TIMBER

ITS STRENGTH, SEASONING, AND GRADING

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ITS STRENGTH, SEASONING, AND GRADING

BY

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AFFECTIONATELY DEDICATED

TO THE MEMORY OF

MY BROTHER

NORMAN DEWITT BETTS

PREFACE

This book is intended primarily for engineers, manufacturers and users of lumber and of various special classes of wood material, and students of engineering and forestry. For such structural materials as steel, concrete, etc., there is a wealth of technical information in readily accessible form. Of wood the same can not be said. It is hoped that the present volume will serve to some extent to supply this deficiency.

The data given are derived almost entirely from tests and investigations on the mechanical properties of wood made by the Forest Service of the U. S. Department of Agriculture. Various bulletins, circulars, and papers of the Forest Service, especially those prepared by the author and those with the preparation of which the author was closely concerned, have been drawn upon freely. Most of the diagrams have already appeared in Department of Agriculture publications.

The author wishes to acknowledge his indebtedness to the members of the Forest Products Laboratory and the Office of Industrial Investigations of the Forest Service for the use made of their publications and for assistance in the preparation of the text, and to thank the various associations for the data they have supplied. Special thanks are due to Mr. Rolf Thelen for his review of the text.

HAROLD S. BETTS.

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TIMBER:

ITS STRENGTH, SEASONING, AND GRADING

CHAPTER I

TIMBER RESOURCES OF THE UNITED STATES

FOREST REGIONS OF THE UNITED STATES—TYPES OF FORESTS—ESTIMATES OF STAND—DIAGRAM AND TABLE SHOWING STAND BY STATES AND SPECIES—TIMBER IN PUBLIC AND PRIVATE OWNERSHIP—FOREST RENEWAL—SHIFTING CENTERS OF PRODUCTION—CHANGE IN SPECIES FORMING BULK OF LUMBER CUT—FUTURE TIMBER SUPPLY OF THE UNITED STATES.

The forest regions of the United States are shown in Fig. 1. Slightly more than one-half of the supply of timber is in the Pacific Northwest (Washington, Oregon, northern Idaho, western Montana, and northern California); about one-fourth of the total amount is in the Southeast; the remainder, except for a small proportion in the Rocky Mountains, is distributed throughout the former centers of production, the Lake States and the Northeastern States. Five groups of States cover the natural timbered areas of the country: the Northeastern States, the Southern States, the Lake States, the Rocky Mountain States, and the Pacific States. In the forests of the two groups last mentioned practically all of the timber-producing trees are conifers. In the first four groups the timber-producing trees are both conifers and hardwoods.

The first heavy timber cutting in the United States was in the white pine forests of the Northeast, and the original stand of white pine has been largely cut out. The present stand in the northeastern States is mainly spruce, second growth white pine, hemlock, and hardwoods.

In the Southern States there are four different types of forests, broadly distinguished according to their elevation above sea

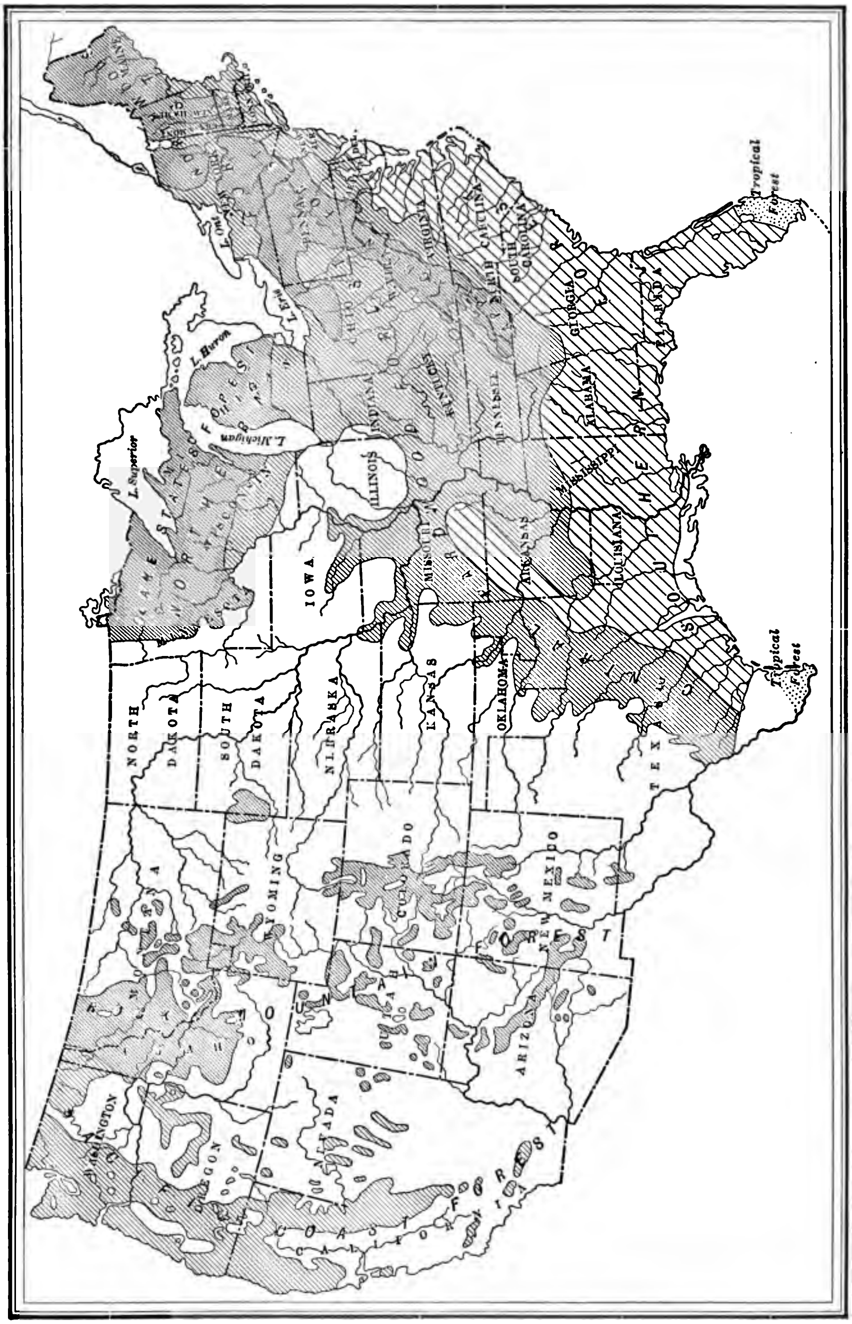


FIG. 1.—Forest regions of the United States.

level. The swamp forests of the Atlantic and Gulf Coasts and the bottom lands of the rivers furnish cypress and hardwoods. The remainder of the coastal plain from Virginia to Texas was originally covered with southern yellow pine. The plateau which encircles the Appalachian Range and the lower part of the mountain region itself support the pure hardwood forest. The higher ridges are occupied by conifers, mainly spruce, white pine, and hemlock.

The Lake States still contain large hardwood forests in their southern portions. In the northern part are coniferous forests made up of the rapidly diminishing white pine and of tamarack, cedar, and hemlock.

The principal timber trees of the Rocky Mountain forests are western yellow pine and lodgepole pine.

The Pacific forests, which contain the largest amount of timber still standing in the United States are largely made up of Douglas fir, western hemlock, sugar pine, western yellow pine, redwood, and cedar.

A number of attempts have been made to estimate the amount of standing timber in these various regions. The most authentic estimates are given in Table 1 (p. 5). It will be seen that they vary widely but that in spite of the continued cutting of our timber the more recent estimates of what is left are larger than those made earlier.

The latest estimate[1] gives the total amount of standing timber in the United States suitable for the manufacture of lumber as 2,826 billion board feet. The original stand has been estimated at 5,200 billion board feet. Of the difference, it is probable that about one-third has been destroyed by forest fires, one-third lumbered, and one-third wasted. Figure 2 shows the estimated stand of the principal species in the various States. The size of the squares indicates the amount of standing timber in the various areas, which in some cases include a number

[1] Paper presented before the International Engineering Congress, Sept., 1915, "Structural Timber in the United States," by H. S. Betts and W. B. Greeley. The estimate in this paper is taken largely from a report of the Bureau of Corporations of the Department of Commerce on "The Lumber Industry," and the Report of the National Conservation Commission. These estimates include, for the most part, only timber of sawlog size, as determined by current requirements. A figure representing the total forest resources of the United States, including fuel, pulpwood, etc., would be materially larger.

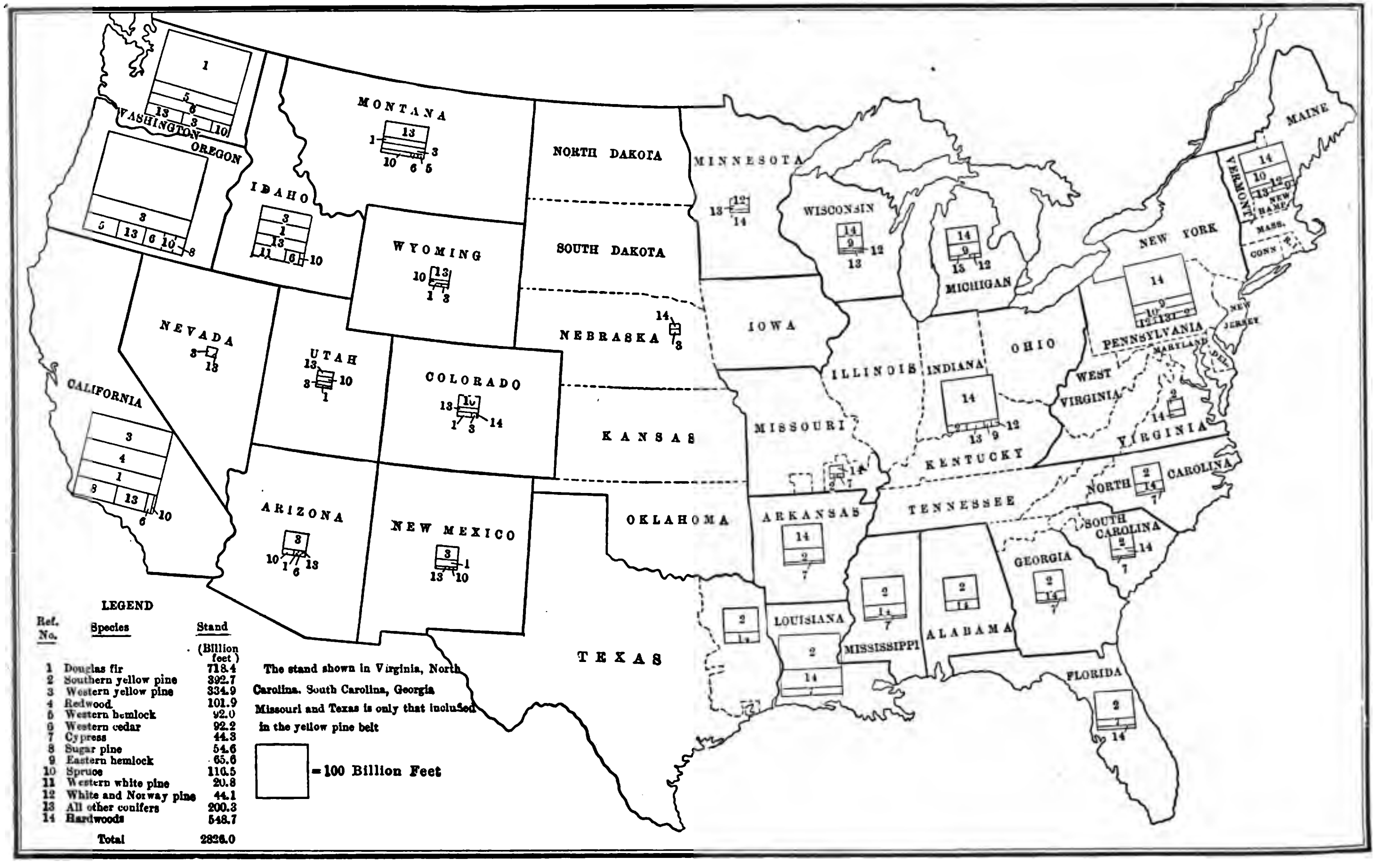


FIG. 2.—Estimated stand of timber in the United States.

TABLE 1.—ESTIMATES OF STUMPAGE IN THE UNITED STATES[1]

Kind of timber	Census, 1880	Hotchkiss, 1898	Census, 1900	Fernow, 1902	Long, 1903	American Lumberman, 1905
	M board feet	M board feet	M board feet	M board feet	M board feet	M board feet
White pine	87,755,000		50,000,000		60,000,000	
Eastern and northern pine						55,000,000
Southern yellow pine	237,141,500		300,000,000		187,250,000	300,000,000
Eastern spruce	12,265,000		50,000,000		18,221,000	75,000,000
Eastern hemlock	20,165,000		100,000,000		56,571,000	100,000,000
Douglas fir			300,000,000		260,000,000	350,000,000
Western yellow pine			125,000,000		138,000,000	250,000,000
Cypress	2,153,600[2]		65,000,000			65,000,000
Redwood	25,825,000		75,000,000		75,000,000	75,000,000
Cedar	22,800,000				27,640,000	
Sugar pine			25,000,000			50,000,000
Other conifers	12,500,000					250,000,000
Total conifers	420,605,100		1,090,000,000		822,682,000	1,570,000,000
Total hardwoods	435,685,000		300,000,000			400,000,000
Region:						
Northern States		100,000,000		500,000,000		
Southern States		300,000,000		700,000,000		
Western States				800,000,000		
Pacific States		1,000,000,000				
Total	856,290,100	1,400,000,000	1,390,000,000	2,000,000,000	822,682,000	1,970,000,000

[1] See Forest Service *Circular* 97 "The Timber Supply of the United States" by R. S. Kellogg.
[2] Florida and Alabama only.

TABLE 2.—ESTIMATED STAND OF TIMBER IN THE UNITED STATES BY SPECIES AND STATES

State	Douglas fir	Southern yellow pine	Western yellow pine	Redwood	Western hemlock	Western cedar	Cypress	Sugar pine	Eastern hemlock	Spruce	Western white pine	White and Norway pine	Other conifers	Hardwoods	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	Billion feet—B. M.														
Alabama	...	38.0	...	...	...	...	0.2	...	...	...	...	...	...	18.1	56.3
Arizona	1.1	...	22.0	...	...	1.1	...	...	...	2.8	...	...	0.8	...	27.8
Arkansas	...	26.9	...	...	...	...	2.4	...	...	...	...	...	...	52.2	81.5
California	77.9	...	114.0	101.9	...	8.0	...	43.7	...	1.5	...	...	34.9	...	381.9
Colorado	3.3	...	1.9	...	...	...	...	...	...	13.3	...	...	4.7	0.2	23.4
Connecticut	...	...	...	...	...	...	...	...	...	...	...	0.7	0.9	3.0	4.6
Delaware	...	0.7	...	...	...	...	...	...	...	...	...	...	...	0.3	1.0
Florida	...	57.1	...	...	...	...	12.6	...	...	...	...	...	...	4.4	74.1
Georgia	...	31.7	...	...	...	...	2.8	...	...	...	...	...	...	11.5	46.0
Idaho	35.2	...	39.1	...	...	9.1	...	...	...	2.6	20.8	...	23.4	...	130.2
Illinois	...	...	...	...	...	...	...	...	...	...	...	...	0.2	5.3	5.5
Indiana	...	...	...	...	...	...	...	...	...	...	...	...	0.1	11.4	11.5
Iowa	...	...	...	...	...	...	...	...	...	...	...	...	...	0.4	0.4
Kansas	...	...	...	...	...	...	...	...	...	...	...	...	...	1.4	1.4
Kentucky	...	...	...	...	...	...	...	...	...	...	...	...	4.3	38.8	43.1
Louisiana	...	67.7	...	...	...	...	15.7	...	...	...	...	...	...	36.4	119.8
Maine	...	...	...	...	...	...	...	...	4.1	26.0	...	...	5.9	23.0	59.0
Maryland	...	2.4	...	...	...	...	...	...	0.2	0.2	...	0.2	1.1	4.7	8.8
Massachusetts	...	...	...	...	...	...	...	...	0.6	0.9	...	5.2	0.2	1.7	8.6
Michigan	...	...	...	...	...	...	...	...	15.0	...	...	2.4	5.8	26.8	50.0
Minnesota	...	...	...	...	...	...	...	...	...	...	...	15.4	7.3	4.8	27.5
Mississippi	...	61.2	...	...	...	...	3.7	...	...	...	...	...	...	27.8	92.7
Missouri	...	1.1	...	...	...	...	0.9	...	...	...	...	...	...	7.9	9.9
Montana	15.1	...	13.0	...	0.5	1.4	...	...	...	6.9	...	...	31.5	...	68.4
Nebraska	...	...	...	...	...	...	...	...	...	...	...	...	...	1.2	1.2
Nevada	...	...	2.0	...	...	...	...	...	...	...	...	...	0.2	...	2.2
New Hampshire	...	...	...	...	...	...	...	...	0.8	5.9	...	5.7	0.6	8 0	21.0
New Jersey	...	...	...	...	...	...	...	...	...	...	...	...	2.3	3.5	5.8
New Mexico	7.7	...	15.5	...	...	...	...	...	...	0.7	...	...	1.0	...	24.9
New York	...	...	...	...	...	...	...	...	10.2	13.3	...	3.1	2.4	49.4	78.4
North Carolina	...	25.6	...	...	...	...	3.0	...	...	...	...	...	...	14.3	42.9
North Dakota	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

State	Douglas fir	Southern yellow pine	Western yellow pine	Redwood	Western hemlock	Western cedar	Cypress	Sugar pine	Eastern hemlock	Spruce	Western white pine	White and Norway pine	Other conifers	Hardwoods	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	Billion feet—B. M.														
Ohio	....	....	......	...	......	......	....	....	......	.....	......	....	0.3	13.5	13.8
Oklahoma	....	....	......	...	......	......	....	....	......	.....	......	....	....	0.1	0.1
Oregon	342.4	....	100.2	...	36.1	20.2	....	10.9	......	11.5	......	....	25.7	....	547.0
Pennsylvania	....	0.5	......	...	......	......	....	....	14.4	.....	......	2.7	....	35.8	53.4
Rhode Island	....	....	......	...	......	......	....	....	......	.....	......	0.3	0.1	0.3	0.7
South Carolina	....	19.2	......	...	......	......	2.6	....	......	.....	......	....	....	8.9	30.7
South Dakota	....	....	3.2	...	......	......	....	....	......	.....	......	....	....	....	3.2
Tennessee	....	6.5	......	...	......	......	....	....	2.0	.....	......	2.0	0.6	54.0	65.1
Texas	....	44.9	......	...	......	......	0.2	....	......	.....	......	....	....	20.9	66.0
Utah	1.2	....	3.6	...	......	......	....	....	......	5.0	......	....	5.3	....	15.1
Vermont	....	....	......	...	......	......	....	....	0.8	1.4	......	1.4	....	7.2	10.8
Virginia	....	8.7	......	...	......	......	0.2	....	......	.....	......	....	....	5.6	14.5
Washington	233.3	....	19.8	...	55.4	51.4	....	....	......	11.9	......	....	23.7	....	395.5
West Virginia	....	0.5	......	...	......	......	....	....	5.2	8.6	......	1.0	....	32.3	47.6
Wisconsin	....	....	......	...	......	......	....	....	12.3	.....	......	4.0	2.8	13.6	32.7
Wyoming	1.2	....	0.6	...	......	......	....	....	......	4.0	......	....	14.2	....	20.0
Total	718.4	392.7	334.9	101.9	92.0	91.2	44.3	54.6	65.6	116.5	20.8	44.1	200.3	548.7	2,826.0

of States or parts of States. The squares are divided into numbered areas indicating the amount of the different species. Table 2 gives the estimates in figures for the stand of timber by States and species. While it should be understood that the data in Fig. 2 are estimates, nevertheless every care has been used in their preparation and the diagram at least indicates the relative amounts of the principal species in various parts of the United States.

About 23 per cent. of the standing timber in the United States, or 673 billion feet, is in public ownership. The most important of the public timber lands are the National Forests, which aggregate 155 million acres, the timbered portions of the Indian Reservations, which total 7 million acres, and Forest Reserves in the ownership of various States, which exceed 3½ million acres. On these areas, broadly speaking, the forests are being cut conservatively, and extended by artificial planting, protection from forest fires is provided, and a continuous production of wood under approved forestry methods is assured.

Aside from these public holdings, however, there is, as yet, little prospect of the scientific renewal of the present enormous forest resources of the United States. Lumbering is still largely the exploitation of virgin timberlands by destructive methods and without regard for the future production of wood, a condition forced upon the industry by its unstable market and the fluctuating, often excessively low, value of its product. Exceptions to this general condition are restricted to small parts of the eastern States, where the practice of forestry is made possible, economically, by exceptionally favorable markets for varied wood products.

The manufacture of lumber in the United States is therefore a nomadic industry, shifting from section to section as the supplies of virgin timber are exhausted. Until 1860, the bulk of the lumber was cut from the Alleghany Mountains and northeastern States. For the next thirty years, the vast white and Norway pine stands of the Lake States furnished most of the country's lumber. The industry then, as represented by the greater part of its mill capacity and outpout, moved into the southern yellow pine belt on the Atlantic and Gulf Seaboard. The production from that section is now at its height, approximately 17 billion feet annually. The total stand of southern yellow pine is estimated at 384 billion feet; hence, twenty years of cutting at the present rate will exhaust it as a large factor in the American lumber trade. In the meantime, the output of the Pacific Coast, already reaching 8 billion feet of Douglas fir in Oregon and Washington, is steadily climbing; it is simply a question of years before it will exceed that of the lumber regions of the East.

The shifting character of the lumbering industry in the United States is seen in the change from period to period in the species of timber making up the bulk of its commercial product. Southern pine is now in very general use as a structural timber; but the movement of the industry to the Pacific Coast is, in the future, going to replace it to a considerable extent with Douglas fir, just as the yellow pine has replaced Norway pine, spruce, and various hardwoods in many structural uses.

It is roughly estimated that the total annual drain upon the forests of the United States from fires, insects, and lumbering combined, including wood for all uses, is around 100 billion board feet. The annual growth of wood in the forests, most of which is a matter of chance rather than of management or scientific method, is probably not over one-third of this amount. The country is thus evidently drawing upon its forest capital at the rate of 60 to 70 billion feet annually. Long before the present enormous forest resources are eaten up, however, it is more than probable that readjusting economic conditions, particularly higher values for timber and a lower per capita consumption, will reduce the annual drain to an amount not more than the annual growth. With its enormous areas of non-agricultural lands—apparently best suited to the production of timber, in the natural order of things—it is probable that the United States will not only supply its own needs but continue to be a large exporter of timber. Even the quality of the lumber placed upon the market, which is of primary interest to the structural engineer, will change but very gradually as old sources of supply renew their stands of merchantable material. For the next thirty or forty years at least, there is no question as to the ability of the United States to furnish high-grade structural timber and lumber from its southern pine and Douglas fir forests to meet almost any demand for such material from any portion of the world.

CHAPTER II

THE STRENGTH OF WOOD

RESULTS OF TESTS ON NORTH AMERICAN WOODS—RELATIONS INDICATED BY TESTS—METHODS OF TESTS

The term strength in a strict sense means ability to resist stress or force of one kind, as strength in bending, strength in compression, etc. However, strength as applied to wood may have a variety of meanings, depending on the use in mind for the wood. In speaking of the strength of columns or posts in buildings, strength in compression is generally meant. In the case of beams, bending strength is thought of. In wood for axe handles, the toughness or shock-resisting ability and hardness are generally included in the term strength. It is evident that strength may include several properties or a single property, according to the use in mind, and that in comparing woods the property or properties must be specified for a clear understanding.

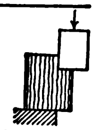
Tests to determine the mechanical properties of wood, such as bending tests, compression tests, shearing tests, hardness tests, etc., to be strictly comparable must be made on straight-grained pieces free from defects, such as knots, shakes, etc., and in the same condition of seasoning. It would manifestly be misleading to compare the strength of oak containing defects with clear hemlock, or the strength of green ash with dry birch.

RESULTS OF TESTS ON NORTH AMERICAN WOODS

Table 3 shows the average mechanical properties of 124 different woods grown in the United States.[1] This table can be used to compare the properties of the different woods, to select woods for particular uses, and to establish correct working stresses. It is based on approximately 130,000 tests conducted by the United States Forest Service over a period of about fifteen years. These tests represent about 80 per cent. of all the tests made on woods grown in the United States.

[1] See U. S. Department of Agriculture Bulletin 556, "Mechanical Properties of Woods Grown in the United States," by J. A. Newlin and T. R. C. Wilson, for a more detailed table.

Hard

Comm	Stiffness 		Hardness 		Shock resisting ability 		Shearing strength parallel to grain 	
	lus city ing	Relative stiffness compared to oak Oak = 100	Load required to imbed a 0.44 inch ball one-half its diameter	Relative hardness compared to oak Oak = 100	Work to maximum load in bending	Relative shock resisting ability compared to oak Oak = 100	Shearing strength	Relative shearing strength compared to oak Oak = 100
		17	18	19	20	21	22	23
	lb. . in.		Lb.		Inch-lb. per cu. in.		Lb. per sq. in.	
Alder, re	67	89	440	42	8.0	60	770	59
Ash, Bi morea	35	102	853	81	11.6	87	1,232	94
Ash, bla	07	84	552	53	11.3	85	866	66
Ash, bla	60	73	....	...	13.1	98	.....	...
Ash, blu	41	95	1,028	98	14.7	111	1,543	118
Ash, gre	19	101	732	70	10.6	80	1,202	92
Ash, gre	80	113	1,007	96	13.0	98	1,318	101
Ash, Or	32	86	790	75	12.2	92	1,191	91
Ash, pu	43	80	752	72	9.4	71	1,214	93
Ash, wh	16	108	1,008	96	13.3	100	1,336	102
Ash, wh	35	125	1,083	103	16.3	123	1,604	123
Ash, wh	85	98	785	75	13.6	102	1,183	91
Aspen (	40	64	318	30	6.9	52	625	48
Aspen la denta	85	90	366	35	6.1	46	813	62
Basswo	49	88	263	25	4.9	37	626	48
Basswo	42	64	222	21	5.8	44	588	45
Beech (	53	103	908	87	14.1	106	1,264	97
Beech (	31	86	740	71	10.9	82	1,155	88
Birch, p	13	77	486	46	15.0	113	786	60
Birch, s	90	114	894	85	15.6	117	1,219	93
Birch, y	90	114	736	70	19.0	143	1,083	83
Birch, y	97	122	754	72	14.2	107	1,145	88
Buckey tandr	81	75	286	27	5.4	41	662	51
Buckth pursh	31	48	731	70	13.4	101	1,151	88
Buttern	08	77	394	38	8.4	63	761	58
Buttern	31	71	379	36	7.9	59	748	57
Cherry,	08	100	664	63	12.8	96	1,127	86
Cherry, vanio	42	79	388	37	6.2	47	677	52
Chestnu	49	72	446	43	7.4	56	845	65
Chestnu	10	69	402	38	6.7	50	749	57
Chinqu chrys	16	77	602	57	9.5	71	1,013	78
Cotton	13	77	344	33	7.3	55	681	52
Cotton tricho	73	82	253	24	5.0	38	601	46
Cucum nata),	65	119	515	49	10.0	75	991	76
Dogwo florid	75	90	1,408	134	21.0	158	1,516	116
Dogwo nutta	90	83	979	93	17.0	128	1,297	99

(*Sheet A.—Facing page 10*)

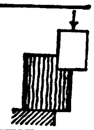
Hardw

Common	…lus …ity …ng	Stiffness: Relative stiffness compared to oak Oak = 100	Hardness: Load required to imbed a 0.44 inch ball one-half its diameter	Hardness: Relative hardness compared to oak Oak = 100	Shock resisting ability: Work to maximum load in bending	Shock resisting ability: Relative shock resisting ability compared to oak Oak = 100	Shearing strength parallel to grain: Shearing strength	Shearing strength parallel to grain: Relative shearing strength compared to oak Oak = 100
		17	18	19	20	21	22	23
Elder, pale	4	69	718	69	8.8	66	1,091	84
Elm, cork (	2	93	....	...	19.4	146		
Elm, cork (	5	89	988	94	20.3	153	1,276	98
Elm, slippe	4	100	722	69	11.7	88	1,185	91
Elm, slippe	5	93	653	62	16.1	121	1,089	83
Elm, white	0	78	546	52	11.2	84	922	71
Elm, white	2	80	....	...	11.8	89	....	...
Greenheart	2	213	1,511	144	12.0	90	1,921	147
Gum, black	1	70	642	61	8.0	60	1,097	84
Gum, blue	6	153	1,344	128	13.9	105	1,546	118
Gum, cotto	4	80	710	68	8.4	63	1,227	94
Gum, cotto	5	80	699	67	7.8	59	1,031	79
Gum red(Li	8	87	....	...	....	...	....	...
Gum red(Li	4	88	522	50	9.4	71	1,072	82
Hackberry	0	89	784	75	19.6	147	1,128	86
Hackberry	1	69	677	65	13.5	102	1,058	81
Haw, pear	4	74	1,204	115	22.7	171	1,356	104
Hickory, b laciniosa)	2	119	....	...	24.3	183	1,162	89
Hickory, b laciniosa)	9	84	....	...	36.2	272	1,212	93
Hickory bit	99	107	....	...	20.0	150	1,237	95
Hickory, m	25	124	....	...	18.6	140	1,270	97
Hickory, m	08	115	....	...	31.7	238	1,282	98
Hickory, m	33	144	....	...	24.1	181	....	...
Hickory, nu caeformis	39	98	....	...	22.8	171	1,031	79
Hickory, pi	55	127	....	...	24.7	186	1,207	92
Hickory, pi	53	118	....	...	27.7	208	1,427	109
Hickory, pi	05	122	....	...	34.9	262	1,358	104
Hickory, pi	59	135	....	...	30.6	230	1,395	107
Hickory, sh	38	125	....	...	16.7	126	1,262	97
Hickory, sh	46	103	....	...	34.1	256	1,421	109
Hickory, sh	92	106	....	...	11.9	89	1,245	95
Hickory, sh	52	134	....	...	18.3	138	1,263	97
Hickory, w	63	119	....	...	18.8	141	1,440	110
Holly, Ame	97	68	792	76	10.8	81	1,130	87
Hornbeam	53	88	1,168	111	13.3	100	1,374	105
Laurel, Ca californic	15	55	1,003	96	16.8	126	1,272	97
Laurel mou	24	70	1,299	124	12.5	94	1,669	128

(Sheet B.—Insert Following Sheet A)

Hard

Comm

		Stiffness 	Hardness 		Shock resisting ability 		Shearing strength parallel to grain 	
	s y k	Relative stiffness compared to oak Oak = 100	Load required to imbed a 0.44 inch ball one-half its diameter	Relative hardness compared to oak Oak = 100	Work to maximum load in bending	Relative shock resisting ability compared to oak Oak = 100	Shearing strength	Relative shearing strength compared to oak Oak = 100
		17	18	19	20	21	22	23
Oak, wil		98	978	93	8.8	66	1,184	91
Oak, yel		93	1,057	101	11.7	88	1,179	90
Oak, yel		86	....	...	13.2	99	....	...
Osage or		101	2,037	194	37.9	285	....	...
Pecan (E		104	1,308	125	14.6	110	1,481	113
Persimm		104	1,279	122	13.0	98	1,474	113
Rhodode dron m		67	864	82	12.1	91	1,240	95
Sassafras		69	524	50	7.1	53	952	73
Serviceb densis)		125	1,244	119	16.2	122	1,256	96
Silverbel carolin		89	470	45	8.8	66	931	71
Sourwoo		100	728	69	9.8	74	1,157	89
Sumach,		62	590	56	10.8	81	....	...
Sugarber		62	739	71	12.0	90	1,049	80
Sycamor		74	580	55	7.1	53	1,001	77
Sycamor		89	638	61	7.9	59	990	76
Umbrell		91	503	48	8.3	62	827	63
Walnut,		108	899	86	14.6	110	1,216	93
Willow,		49	383	37	8.7	65	685	52
Willow,		37	334	32	12.9	97	561	43
Willow, lasianc		78	501	48	10.8	81	866	66
Witch h ana)..		85	977	93	19.5	147	1,118	86
Yellow tulipif		92	338	32	5.6	42	787	60

NOTE.—) The strength value given (modulus of elasticity in bending) is for green wood. This strength value is about 25 per cent. greater for air-dry wood than for the green.

(3) The strength value given (side hardness) is for green wood. It is an average of the values for radial and tangential hardness. This strength value is about 33 per cent. greater for air-dry wood than for the green.

(4) The ability of the wood to resist shock is a combination of strength and toughness.

(5) The strength value given (shearing strength) is for green wood. It represents an average of the values for radial and tangential shearing strength. This strength value is about 50 per cent. greater for air-dry wood than for the green. The shearing strength of kiln-dried wood is greater than that of air-dry wood.

(3, 4 & 5

(6

(Sheet D.—Insert Following Sheet C)

Conife

Commo	dulus of ticity in ding	Stiffness: Relative stiffness compared to oak Oak = 100	Hardness: Load required to imbed a 0.44 inch ball one-half its diameter	Hardness: Relative hardness compared to oak Oak = 100	Shock resisting ability: Work to maximum load in bending	Shock resisting ability: Relative shock resisting ability compared to oak Oak = 100	Shearing strength parallel to grain: Shearing strength	Shearing strength parallel to grain: Relative shearing strength compared to oak Oak = 100
	6	17	18	19	20	21	22	23
Cedar, i currens)	926	71	389	37	6.4	48	834	64
Cedar, i currens)	754	58	...	..	...	..	...	..
Cedar, P paris la	,497	114	475	45	7.8	59	881	67
Cedar, we	886	68	246	23	4.5	34	697	53
Cedar, we	021	78	272	26	5.6	42	742	57
Cedar, wh	643	49	226	22	5.7	43	615	47
Cypress, tichum)	,378	105	354	34	5.1	38	822	63
Cypress, tichum)	,061	81	403	38	7.3	55	822	63
Cypress, nootka	965	74	408	39	9.5	71	820	63
Fir, amab	,323	101	...	..	...	..	...	..
Fir, amab	,257	96	310	30	6.0	45	673	52
Fir, Alpin	861	66	219	21	4.4	33	613	47
Fir, balsa	964	74	291	28	4.7	35	612	47
Fir, Dou folia)..	,376	105	423	40	6.2	47	781	60
Fir, Dou folia)..	,508	115	524	50	6.8	51	961	74
Fir, Dou folia)..	,242	95	408	39	7.0	53	855	65
Fir, Dou folia)..	,679	128	514	49	7.0	53	881	67
Fir, Dou folia)..	,407	107	427	41	6.1	46	940	72
Fir, Dou folia)..	,623	124	480	46	6.8	51	906	69
Fir, Dou folia)..	,597	122	...	..	...	..	...	..
Fir, Dou folia)..	,122	86	393	38	6.5	49	897	69
Fir, gran	,311	100	375	36	6.2	47	735	56
Fir, gran	,286	98	348	33	5.0	38	786	60
Fir, noble	,281	98	254	24	6.2	47	698	53
Fir, white	,131	86	328	31	5.2	39	732	56
Hemlock	,330	101	468	45	6.9	52	951	73
Hemlock	917	70	344	33	6.6	50	801	61
Hemlock siana)	936	71	464	44	9.4	71	884	68
Hemlock phylla)	1,192	91	432	41	6.0	45	808	62
Hemlock phylla)	1,428	109	...	..	...	..	....	..
Larch, we	1,369	104	452	43	7.1	53	917	70
Larch, we	1,310	100	...	..	...	..	....	..
Pine, Cu	1,631	124	628	60	7.9	59	1,033	79
Pine, jac	921	70	366	35	5.9	44	759	58
Pine, Jef	982	75	342	33	4.7	35	694	53
Pine, lob	1,431	109	452	43	8.0	60	903	69

(*Sheet E.—Insert Following Sheet D*)

Conifers

Common an	Stiffness		Hardness		Shock resisting ability		Shearing strength parallel to grain	
	dulus of ticity in nding	Relative stiffness compared to oak Oak = 100	Load required to imbed a 0.44 inch ball one-half its diameter	Relative hardness compared to oak Oak = 100	Work to maximum load in bending	Relative shock resisting ability compared to oak Oak = 100	Shearing strength	Relative shearing strength compared to oak Oak = 100
	16	17	18	19	20	21	22	23
	,293	99	...	...	...	...	....	...
Pine, loblolly (	,015	77	312	30	5.1	38	710	54
Pine, lodgepo	,128	86	323	31	4.9	37	679	52
Pine, lodgepo	,081	87	350	33	6.0	45	670	51
Pine, lodgepo	,142	87	347	33	6.3	47	665	51
Pine, lodgepo	972	74	318	30	5.3	40	714	55
Pine, lodgepo	,615	123	602	57	7.6	57	1,066	82
Pine, longleaf	,752	134	664	63	8.9	67	1,150	88
Pine, longleaf	,653	126	595	57	8.1	61	1,062	81
Pine, longleaf	,662	127	512	49	8.1	61	1,006	77
Pine, longleaf	,406	107	526	50	7.0	53	1,034	79
Pine, longleaf	,118	85	484	46	8.5	64	949	73
Pine, pitch (P	,281	98	510	49	7.5	56	936	72
Pine, pond (P	,384	106	342	33	5.8	44	776	59
Pine, Norway	1,395	106	...	...	...	...	708	54
Pine, shortlea	1,506	115	558	53	8.7	65	1,071	82
Pine, shortlea	966	74	324	31	5.0	38	708	54
Pine, sugar (I								
Pine, Table-pungens). .	1,271	97	494	47	8.1	61	955	73
Pine, western ticola).....	1,329	101	333	32	5.1	38	711	54
Pine, weste ponderosa)	879	67	314	30	4.9	37	662	51
Pine, weste ponderosa)	1,111	85	314	30	4.3	32	696	53
Pine, weste ponderosa)	1,053	80	331	32	6.0	45	705	54
Pine, weste ponderosa)	865	66	322	31	5.2	39	674	52
Pine, weste	1,160	88	...	...	...	...	....	...
ponderosa)	1,073	82	296	28	5.9	44	644	49
Pine, white (	1,024	78	...	...	...	...	....	...
Redwood (Se	1,101	84	...	...	...	...	....	...
Redwood (Se								
Spruce, Eng manni)...	798	61	221	21	5.0	38	569	44
Spruce, Eng	866	66	264	25	4.8	36	615	47
manni)...	1,143	87	349	33	6.0	45	768	59
Spruce, red (	1,215	93	346	33	6.2	47	764	58
Spruce, red (	1,185	90	369	35	6.4	48	777	59
Spruce, sitka	968	74	274	26	6.6	50	630	48
Spruce, whit	988	75	278	27	5.4	41	691	53
Spruce, whit	1,236	94	375	36	7.2	54	863	66
Tamarack (L	989	75	1,150	110	20.2	152	1,621	124
Yew, wester								

(Sheet F.—Insert Following Sheet E)

Small clear specimens were used. Each line of the table represents the average of tests made on pieces cut from five typical trees from a single locality.[1] Since there is considerable variation in the strength of wood from individual trees of the same species, the results should be taken as indications rather than as fixed values.

Table 3 gives average values obtained from tests on green material. The values for dry material would be higher, as indicated in the accompanying notes. While it is true that the properties of all species are not changed in the same proportion by drying and that all the properties are not equally affected, nevertheless the converting factors given in the notes will indicate with sufficient accuracy for most practical purposes the strength to be expected in the dry material.

The first column in Table 3 gives the common and botanical names of the species. Since many species have a number of common names, some of which may be used for several species in different parts of the country, the botanical name is needed for positive identification. The locality where grown as shown in the second column of Table 3 should not be given too much weight as an indication of strength or weakness. The influence of region of growth on the properties of wood is generally overemphasized.

The columns numbered 3, 4, and 5 give the weight per cubic foot in three conditions of moisture—green, air dry, and kiln dry. The weight in a green condition was determined at the time the logs were sawed into pieces for test. The various species differ largely as to the wetness of the green wood. The hardwoods as a rule do not exhibit any considerable variation in moisture with the position in the tree. The conifers, on the other hand, show a wide variation in moisture content between the heartwood and sapwood and in some instances between the upper and lower parts of the tree. Tamarack and cypress, however, have a comparatively uniform moisture content throughout the tree. Sugar pine and western larch are frequently very heavy, because of moisture in the former and resin at the butt in the latter. Longleaf pine and some other species have a very low moisture content in the heartwood, while the sapwood is very wet. When this is the case, young thrifty trees with a large propor-

[1] The averages for a few of the species listed in Table 3 are from less than five trees.

tion of sapwood are much heavier than old over-mature trees with a small amount of sapwood. The weight in an air dry condition was determined after the test material had dried to constant weight under shelter. The moisture content under such conditions is generally from 12 to 15 per cent. It varies with the part of the country in which the drying or seasoning takes place. An air dry condition in Douglas, Arizona, would mean a considerably lower moisture condition than an air dry condition in Seattle, Washington. The weight in a kiln dry condition was determined by adding 8 per cent. to the weight of the bone dry wood.[1] Of course, kiln dried material may be dried so that it has more or less than 8 per cent. moisture, depending on conditions in the kiln. Eight per cent. is considered an average moisture content for kiln dried wood.

In the determination of the figures for specific gravity based on volume when green (column 6), the test specimens are weighed and measured when green. Their oven dry weight is then computed by dividing the weight when green by one plus the proportion of moisture. Specific gravity based on volume when green is unaffected by the shrinkage of the wood. Specific gravity is the best criterion, except actual strength tests, of the strength of the clear wood of any species.

It has been found that in oak, more than in any other species or group of closely related species, pieces of the same density may vary widely in mechanical properties. Occasionally very dense pieces of oak are for some unknown reason low in strength; but in all species, specimens of low density are invariably weak.

The per cent. of shrinkage that occurs when a piece of wood is dried from a green condition to an oven dry or bone dry condition is shown in the columns numbered 7, 8, and 9. All shrinkages are expressed in percentages of the original or green dimensions. In practice, wood is seldom if ever dried to an oven dry condition. It is generally either kiln dry or air dry. The shrinkage to be expected in drying green material to a kiln dry condition may be taken as 75 per cent. of the shrinkage from a green to a bone dry condition; and the shrinkage from a green to an air dry condition as 50 per cent. or one-half the shrinkage to a bone dry condition. Column 7 gives the shrinkage in volume, omitting longitudinal shrinkage, which is negligible. Columns 8 and 9 give the shrink-

[1] For accurate calculations the swelling from 0 to 8 per cent. moisture and the consequent reduction in specific gravity must be taken into account.

age in the radial and tangential directions respectively. The radial shrinkage is roughly one-half as much as the tangential shrinkage. Radial shrinkage is a measure of the change in width of a quarter-sawed or edge-grain board. If such a board of Douglas fir 10 inches wide were dried so that the moisture was reduced from 30 per cent. to 15 per cent. (green to air dry condition) the decrease in width would be about $3/16$ inch. Tangential shrinkage is a measure of the change in the width of a flat-grain board. In a 10-inch flat-grained Douglas fir board the decrease in width when dried from 30 per cent. to 15 per cent. moisture would amount to about $5/16$ inch.

Columns 10 and 11 show, respectively, the modulus of rupture or breaking strength in bending in pounds per square inch and the strength compared to oak. The modulus of rupture is a measure of the ability of a beam to support a slowly applied load for a short time. Safe working stresses for carefully selected structural timbers, such as floor joists, stringers, etc., with all exceptionally light pieces excluded, subjected to bending in dry interior construction, are about one-sixth the modulus of rupture values given in Table 3. The values given are for green wood. The modulus of rupture for air dry wood is about 50 per cent. greater than that for green. For kiln dry wood it is about 100 per cent. greater, or twice the green value. This increase in strength due to drying does not apply to comparatively large structural timbers, in which the defects induced in the drying process, such as checks and shakes, frequently offset any increase in the strength of the wood itself.

Columns 12 and 13 give, respectively, the crushing strength for green wood in pounds per square inch and the strength compared to oak. For air dry wood the crushing strength is about 50 per cent. greater than for the green, and for kiln dry wood the strength is about 100 per cent. greater, or twice the strength of the green. The maximum crushing strength is a measure of the ability of a short block to sustain a slowly applied load. It is important in calculating the strength of short columns. A safe working stress is about three-tenths the crushing strength as given.[1]

Columns 14 and 15 give the strength in compression perpendicular to the grain and the relative strength compared to oak. Fiber stress at elastic limit is the value given. It

[1] In dry interior construction, and with light weight pieces excluded.

represents the greatest stress that can be applied without injury and is used in computing the proper bearing area for beams, railroad ties, etc. Two-thirds of the fiber stress given in Table 3 may be used as a safe stress in dry interior construction.

Columns 16 and 17 show the modulus of elasticity in bending in 1000 pounds units and as compared to oak. The modulus of elasticity is a measure of stiffness and is used in calculating the deflection of beams. A high modulus of elasticity means a high degree of stiffness with but little deflection. One-half the values given in the table are recommended for use in the design of structures on account of variations in the quality of timber and inaccuracies in workmanship in fitting together the various parts.

Columns 18 and 19 show the hardness as indicated by the load required to imbed a steel ball in the various species of wood and as compared to oak. Hardness is important in flooring, handles of various kinds, paving blocks, vehicle material, etc. There appears to be no consistent difference between the hardness on a radial surface and on a tangential surface, and both values are averaged and tabulated as "side hardness." End hardness (not given) is usually slightly greater than side hardness.

Columns 20 and 21 show the work to maximum load in bending in inch pounds per cubic inch and as compared to oak. The work to maximum load is a measure of the shock-resisting ability, or combined strength and toughness. It is important in estimating the relative fitness of woods for uses where they are subjected to sudden loads as in wagon or automobile spokes or axe handles. Hickory and osage orange are woods that rank especially high in shock-resisting ability.

Columns 22 and 23 show the shearing strength parallel to the grain and the shearing strength compared to oak. Shearing strength is important in beams which are likely to fail by shearing lengthwise so that the upper half slides on the lower half when the beam bends.

RELATIONS INDICATED BY TESTS

1. The density or dry weight of wood is a measure of its strength.

2. Each annual growth ring is made up of a comparatively heavy band of summerwood and a lighter band of springwood. The greater the proportion of summerwood, the greater the weight and strength of the timber.

3. No differences in mechanical properties due to a change from sap to heart have been found. As a general rule, in species which show a variation in the mechanical properties with position in cross sections, there is a certain age when the best wood is produced. In such species the age and thrift of the tree determine whether heart or sap is the better. For example, in a young, thrifty hickory the sapwood is usually the better; while in a large, over-mature tree of the same species the heartwood is the better.

4. Exceedingly rapid or slow growth in conifers has usually been found to be attended by lack of density and inferior mechanical properties.

5. The effect of location of growth on the nature of the timber is very complex. Variations attributed to difference in locality of growth are frequently exaggerated. These variations are generally apparent in the difference in density of the wood.

6. Trees growing close together and apparently under the same conditions occasionally show a difference in their mechanical properties that can not be entirely accounted for by the difference in density. Whether this difference is due to the ancestry of the tree or some other cause, such as soil conditions, is not yet known.

7. The strength of small, clear pieces is greatly increased by seasoning. In large timbers, the increased strength attending a loss of moisture is mostly offset by checks and other defects developed during the seasoning process, and therefore, under most conditions it is not considered advisable to anticipate any added strength due to seasoning.

METHODS OF TEST

The methods of test[1] used in obtaining the data in Table 3 are shown in Figs. 3 to 10 inclusive.[2] With each figure is a

[1] For a more detailed description of the methods of test used by the Forest Service see Forest Service *Circular* 38, "Instructions to Engineers of Timber Tests," revised, Forest Service *Bulletin* 108, "Tests of Structural Timbers," by McGarvey Cline and A. L. Heim, and a paper presented at the 6th Congress of the International Association for Testing Materials, "Forest Service Investigations of American Woods with Special Reference to Investigations of Mechanical Properties," by McGarvey Cline.

[2] Several methods of testing wood not referred to in Table 3 are given for the sake of completeness.

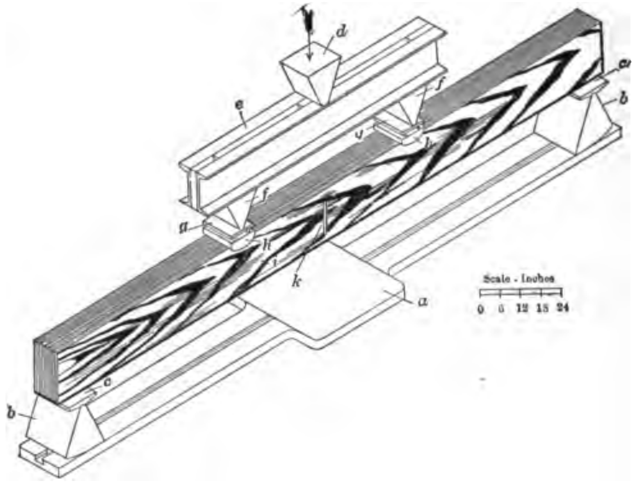


FIG. 3.—Bending test, 8″ × 16″ × 16′ bridge stringer.

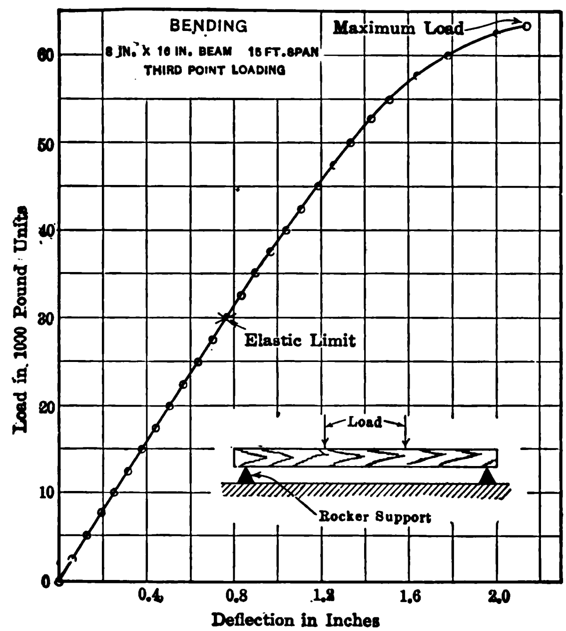


FIG. 3a.—Stress strain diagram for bending test.

FIGS. 3 and 3a.—Method of testing large beams in bending and resulting diagram.

DESCRIPTION OF FIGS. 3 AND 3*a*.

Specimen.—Contains defects common in material bought on the market. The commercial grade is determined by the number, size, and position of these defects. Bridge stringer, 8″ × 16″ × 16′.

Set Up.—Specimen rests on rocker supports (*b*), with bearing plates (*c*) between the supports and the specimen. The supports rest on extension arms bolted to the weighing platform (*a*) of a universal testing machine.

Load is applied continuously at the two points (*h*, *h*) each one-third length of span from end supports. Load is applied by the machine head at (*d*) and transmitted through the double channel beam (*e*) and through the roller bearings (*g*, *h*) to the specimen. Speed of machine 0.25 inch per minute.

Deformation.—Deflections at center are measured by a fine wire (*i*) kept taut by a spring stretched between two nails driven midway between the top and bottom faces of the specimen vertically above the supports. The wire crosses a steel scale (*k*) attached to the specimen. The movement of the wire with reference to the scale shows the amount of bending.

Results Calculated.—(*a*) Fiber stress at elastic limit. This is the greatest stress that can occur in a beam loaded with an external load from which it will recover without permanent deflection.

(*b*) Modulus of rupture. This is the greatest computed stress in a beam loaded with a breaking load.

(*c*) Modulus of elasticity. This is a factor computed from the relation between load and deflection within the elastic limit, and represents the stiffness of the wood fiber.

(*d*) Longitudinal shear. This is the stress tending to split the beam lengthwise along its neutral plane when under maximum load.

(*e*) Work to maximum load. This is the energy or work required to bend the beam to its deflection at maximum load. It is a measure of a combination of strength and toughness or shock-resisting ability.

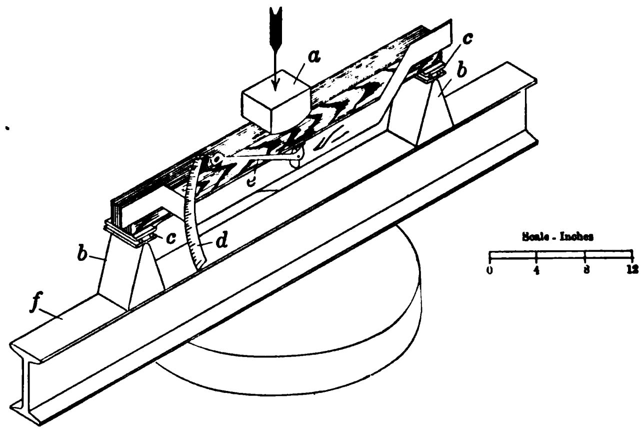


FIG. 4.—Method of testing small beams in bending.

Specimen.—Clear, straight-grained, 2″ × 2″ × 30″.

Set Up.—1. I-beam, (*f*), with two knife-edge supports, (*b b*), 28 inches apart, placed on weighing platform of universal testing machine.

2. Specimen rests on knife-edge supports, (*b b*), with roller bearings, (*c c*), interposed between the supports and the specimen.

3. Load applied continuously at center of span through the bearing block (*a*); speed of machine 0.105 inch per minute.

Deformation.—Deflections at center measured by means of special deflectometer, (*d e*). The deflectometer rests upon small nails driven vertically above the knife-edge supports midway between the top and bottom faces of the specimen. The indicator, (*e*), is fastened by means of a thin strip of steel to a small nail on the neutral axis midway between the supports. As the beam deflects, the indicator drops by gravity, indicating on the scale, (*d*), the amount of deflection to the nearest one-thousandth of an inch. Deflections are observed for every 50 pounds increment of load.

Results Calculated.—(*a*) Fiber stress at elastic limit.

(*b*) Modulus of rupture.

(*c*) Modulus of elasticity.

(*d*) Work to maximum load.

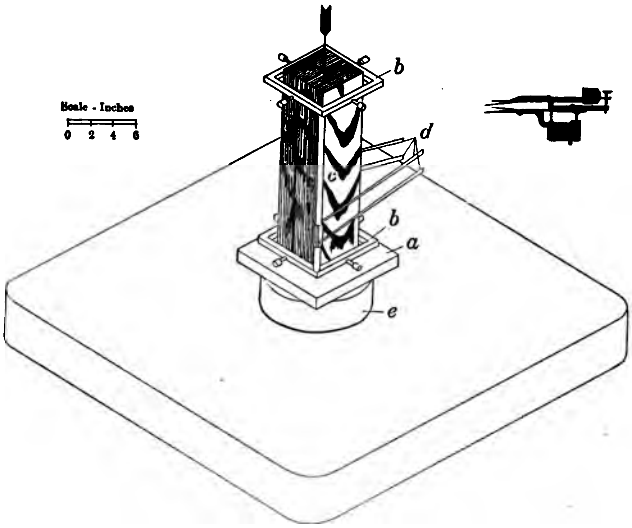


FIG. 5.—Compression parallel to grain.

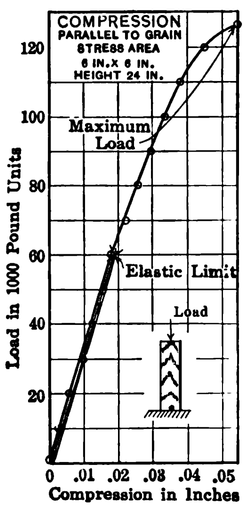


FIG. 5*a*.—Stress strain diagram for compression test.

FIGS. 5 and 5*a*.—Method of making a test in compression parallel to grain, and resulting diagram.

Specimen.—Clear, straight-grained, 2″ × 2″ × 8″; ends carefully squared.

Set Up.—1. Yokes, (*b b*), placed on specimens 6 inches apart, held in place by thin, pointed screws.

2. Specimen rests on ball and socket bearing, (*a e*); load applied continuously; speed of machine 0.024 inch per minute; care should be taken to have the ends of the specimen cut smooth and true so that the load is distributed uniformly over the ends.

Deformation.—Deformation between yokes measured by means of Olsen compressometer. The arms of the compressometer are brought in contact with the yokes, (*b b*), by means of the spacing bars, (*c c*).

Results Calculated.—(*a*) Fiber stress at elastic limit.

(*b*) Maximum crushing strength.

(*c*) Modulus of elasticity.

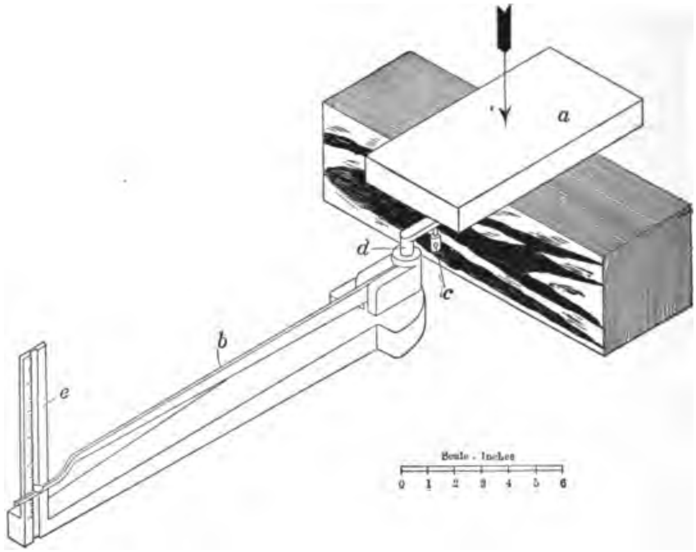


Fig. 6.—Compression perpendicular to grain.

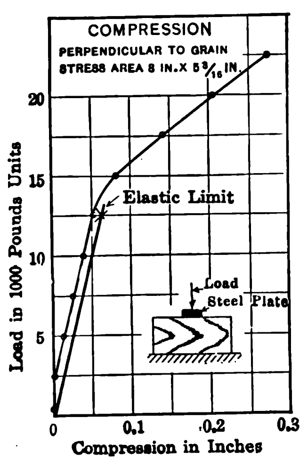


Fig. 6a.—Stress strain diagram for compression test.

Figs. 6 and 6a.—Method of making a test in compression perpendicular to grain, and resulting diagram.

Specimen.—Clear, straight-grained, 2″ × 2″ × 6″.

Set Up.—Specimen placed on weighing platform of universal testing machine. Steel plate, (*a*), 2 inches wide placed on top of specimen. Load applied to the specimen through the plate, (*a*); speed of machine 0.024 inch per minute.

Deformation.—Deformations measured with deflectometer, (*d*, *b*, *e*), the bearing end of the deflectometer coming in contact with steel plate, (*a*).

Results Calculated.—Crushing strength at elastic limit. The load at elastic limit is determined by means of load-deformation diagram.

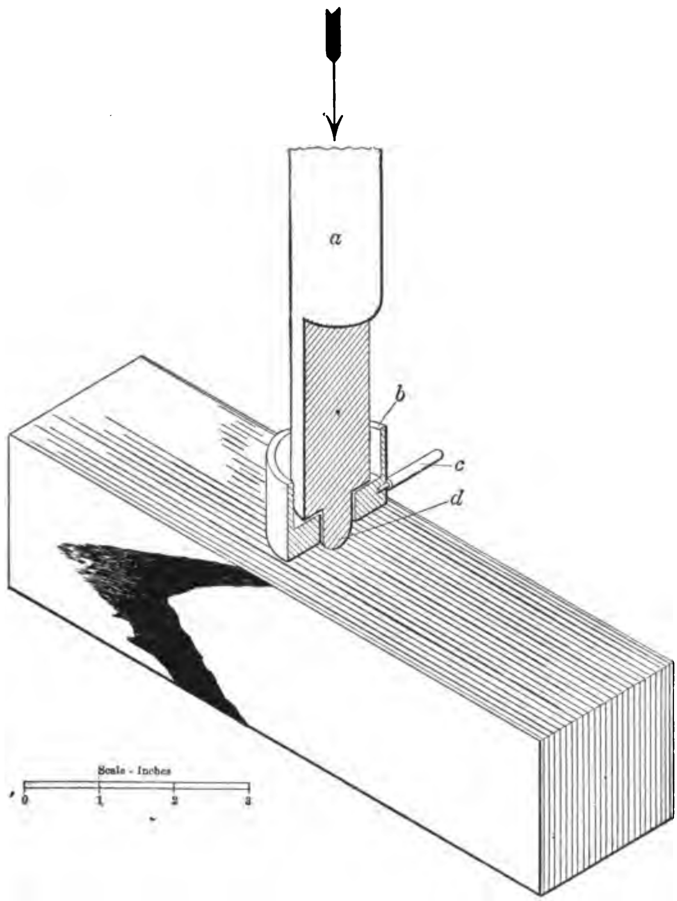


FIG. 7.—Method of making test for hardness.

Specimen.—Clear, straight-grained, 2″ × 2″ × 6″.

Set Up.—Steel bar, (*a*), held rigidly in crosshead of testing machine. The end of bar, (*a*), is a hemisphere, having a diameter of 0.444 inch. During test, washer, (*b*), is kept moving by operator by means of handle, (*c*). When end of bar, (*a*), is forced into the wood, the distance equal to radius of the sphere, the washer, (*b*), becomes fixed. The load at the instant the washer becomes fixed is taken as a measure of the hardness. The hardness test is made on radial and tangential faces as well as on the ends of the specimen.

Results Calculated.—Load in pounds to imbed sphere .44 inch diameter, a distance equal to its radius.

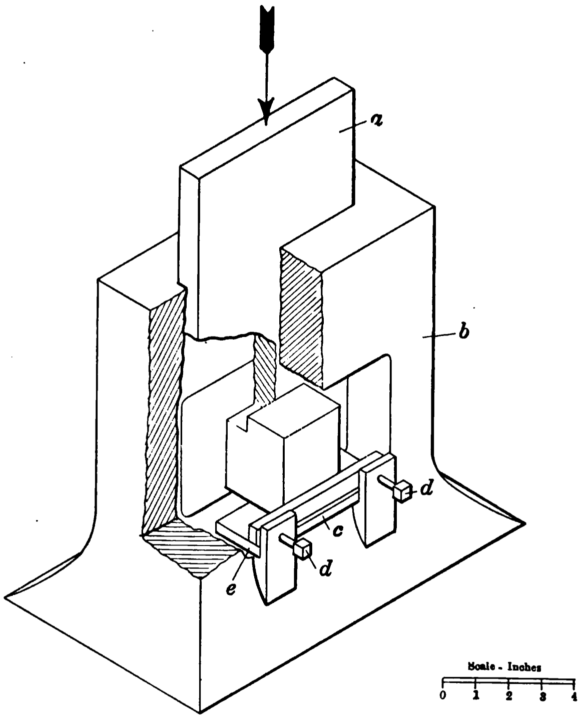


FIG. 8.—Method of making shearing test.

Specimen.—Clear, straight-grained, cut so as to have a projecting shoulder.

Set Up.—1. Specimen placed in shearing tool so that a movable plate rests upon projecting shoulder.

2. Specimen rests upon plate, (*e*), and is held in a vertical position by means of plate, (*c*), and screws, (*d, d*).

3. Shearing tool rests upon base of universal testing machine; load is applied to specimen through plate, (*a*); the load is increased gradually; speed of machine 0.015 inch per minute, until projecting part of specimen is sheared off.

Results Calculated.—Maximum shearing strength in pounds per square inch.

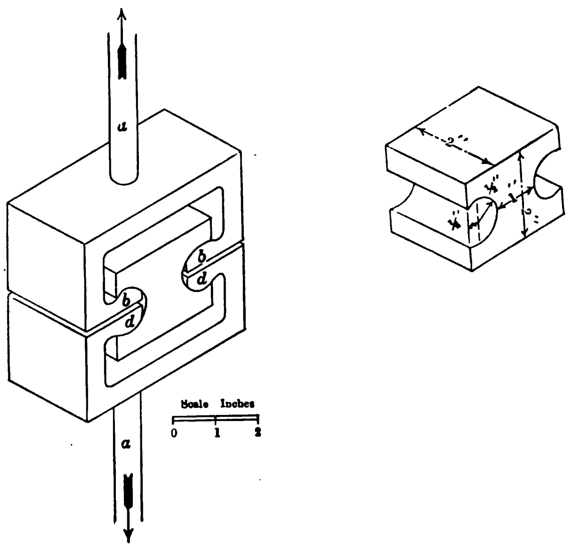


FIG. 9.—Method of making test in tension at right angles to grain. Specimen 2″ × 2″ × 2½″.

Specimen.—(See Figure.)

Set Up.—1. Holders, (*b b*), and (*d, d*), fastened to fixed and movable cross-heads of universal testing machine by means of rods, (*a a*), which are connected to holders with ball and socket joints.

2. Specimen placed in holders, (*b b*), and (*d d*), so that bearing of holders or specimen is uniform over entire length of specimen.

3. Load applied gradually, speed of machine 0.25 inch per minute.

Results Calculated.—Maximum tensile strength in pounds per square inch.

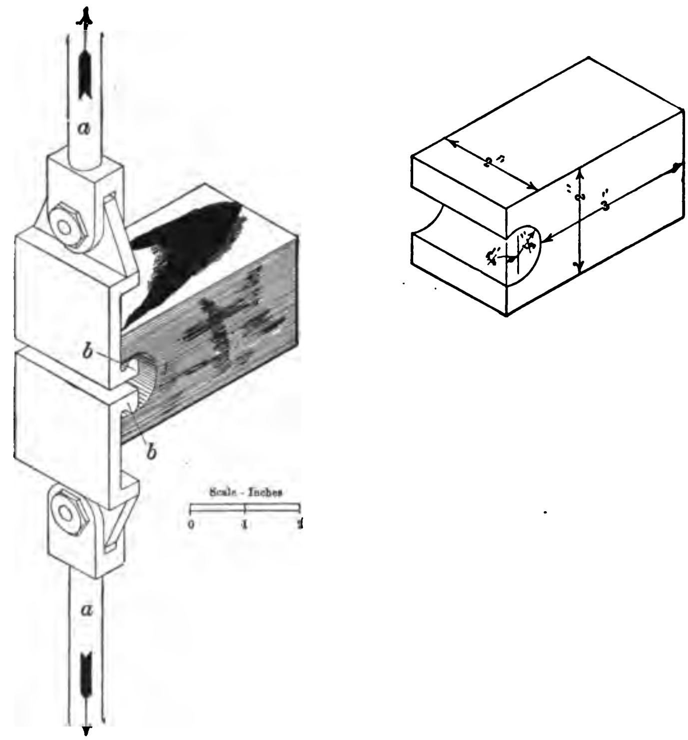


FIG. 10.—Method of making cleavability test.

Specimen.—(See Figure.)

Set Up.—1. Holders, (*b b*), fastened to fixed and movable crossheads of machine by rods, (*a a*.)

2. Specimen placed so that one end rests snugly against holders so that distance from contact point to line of maximum stress is constant (½ inch).

3. Load applied gradually; speed of machine 0.25 inch per minute.

Results Calculated.—Maximum load divided by width of specimen in inches.

brief description of the method and meaning of the values derived from the tests. In addition to these values moisture determinations and specific gravity determinations are made on each test specimen and the specimen is carefully described. Typical stress-strain diagrams for three kinds of tests—bending, compression parallel to grain, and compression perpendicular to grain—are shown.

Method of Determining Moisture Content of Wood

1. Saw a section 1 inch thick from the piece of lumber whose moisture is to be determined. The section should be taken

at least 12 inches from an end as the wood close to the ends is liable to contain less moisture than the average for the whole stick, due to end drying.

2. Remove splinters from section and weigh (W). An accuracy of 1 per cent. is sufficient. Mark weight on section.

3. Dry section in oven at 100° C. (212° F.) until weight (W_1) is constant. If an oven is not available, the section may be dried on hot steam pipes until it ceases to lose weight.

4. The first weight (W) minus the dry weight (W_1) represents the weight of water dried out of the wood. Divide this loss by the dry weight and multiply by 100. The result is the moisture content (M) of the wood expressed in per cent. of the dry weight.

$$M = \frac{W - W_1}{W_1} \times 100$$

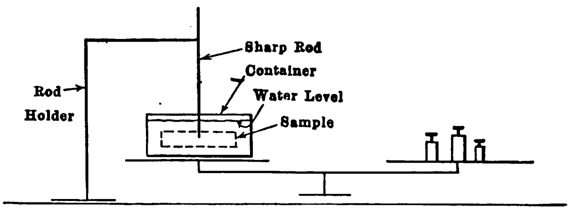


FIG. 11.—Method of determining volume by displacement of water.

METHOD OF DETERMINING SPECIFIC GRAVITY OF WOOD SPECIMENS

1. Cut typical samples from specimen containing from 5 to 25 cubic inches.

2. Find volume (V) of sample in cubic centimeters by measurements or by displacement method (see below).

3. Dry sample in oven at 212° F. (100° C.) until weight is constant.

4. Find weight (W) of sample in grams.

5. Divide weight of sample by volume of sample $\frac{W}{V}$ = specific gravity.[1]

[1] This is specific gravity based on volume at test. To find specific gravity based on oven dry volume weigh sample after drying and divide by oven dry volume. This will be larger than specific gravity based on volume with more moisture, since sample shrinks in drying.

Method of Determining Volume by Displacement of Water (See Fig. 11)

Place a container partly filled with water on one pan of a balance scale and bring to balance. Stick the sample whose volume is to be determined on one end of a sharp metal rod. Dip sample in paraffine and place under water in container. Adjust the rod in holder so that the sample is held under water but does not touch container. Balance scales again. The operation of weighing under water should be carried out rapidly so as to prevent absorption of water by the sample. Since a cubic centimeter of water weighs one gram the weight in grams required to balance scales after the sample is submerged is the volume of the sample in cubic centimeters.

CHAPTER III

EFFECT OF MOISTURE AND OF PRESERVATIVE AND CONDITIONING TREATMENTS ON THE STRENGTH OF WOOD

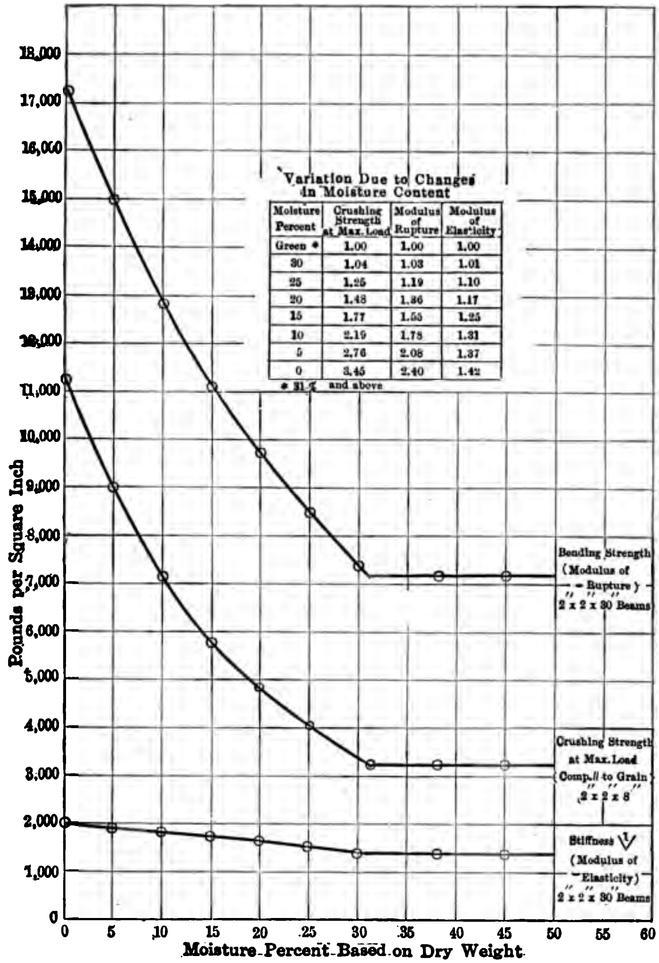
EFFECT OF MOISTURE

Moisture exists in wood in two conditions—absorbed in the cell walls, and filling the various open spaces or cavities in the cells. The water in the open spaces, "free" water, has no effect on the strength. If a piece of green wood is dried, it first loses the free water; and until this is gone and the water in the cell walls begins to grow less the strength remains the same. The reduction of moisture in the cell walls causes an increase in strength. The relation between moisture and bending strength, crushing strength, and stiffness for western hemlock is shown in Fig. 12. It may be seen that above about 30 per cent. moisture there is no change in strength, while if the moisture is reduced below 35 per cent. the strength increases rapidly. The effect of moisture on stiffness is comparatively slight. Moisture strength diagrams for all the more common structural species have the same general form as that for western hemlock. Fig. 13 shows the relation between moisture and crushing strength for a number of woods.

When the cell walls have absorbed all the moisture they can the wood is said to be at the fiber saturation point. If the wood takes up more moisture, the additional moisture will be contained in the form of free water in the cell cavities. The fiber saturation point for various species appears to vary between 20 and 35 per cent. moisture.

Figure 14 shows the results of crushing tests on longleaf pine, eastern spruce, and chestnut, including pieces varying from an oven dry to a soaked condition. The oven dry pieces have practically no moisture and had the greatest crushing load. They were also the stiffest as shown by the angle between the horizontal compression scale and the line marked "oven dry" on the diagram. The greater this angle the stiffer is the piece.

The kiln dry pieces, with slightly more moisture than the oven dry pieces, rank next in strength and stiffness followed by several air dried pieces with increasing moisture and lower strength.



Variation Due to Changes in Moisture Content

Moisture Percent	Crushing Strength at Max. Load	Modulus of Rupture	Modulus of Elasticity
Green *	1.00	1.00	1.00
30	1.04	1.03	1.01
25	1.25	1.19	1.10
20	1.48	1.36	1.17
15	1.77	1.55	1.25
10	2.19	1.78	1.31
5	2.76	2.08	1.37
0	3.45	2.40	1.42

* 31% and above

FIG. 12.—Effect of varying degrees of moisture upon the strength and stiffness of small clear pieces of western hemlock.

The pieces that were dried and then allowed to reabsorb moisture in a humid atmosphere and the pieces that were dried and then resoaked were the weakest and least stiff of any.

It should be noted in the case of specimens dried so as to cause

[1] Read scale in 1,000 pounds per square inch.

an uneven distribution of moisture throughout the cross section that the resulting moisture strength curve will be above the curve for evenly dried specimens, and will be gradually rounded off from the wettest to the driest condition. Figure 15 shows the strength of case hardened or unevenly dried pieces as compared with pieces dried uniformly throughout their cross section. This

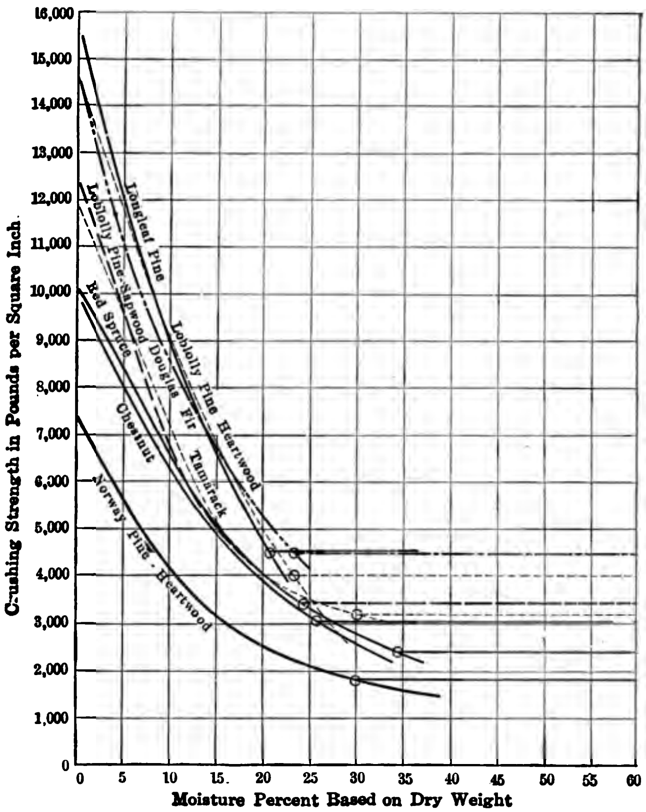


FIG. 13.—Relation between the crushing strength in compression parallel to grain, and the moisture content for several woods.

condition of uneven dryness will generally be true of structural material. The specimens used in Fig. 15 were somewhat case-hardened, as a result of the surface being more rapidly seasoned than the interior; and on this account the diagram is rounded instead of making a sharper angle at the fiber saturation point. The strength of small, clear pieces of wood when dried from a green to a kiln dry condition is frequently doubled.

In considering the effect of moisture on wood, it should be kept in mind that a considerable increase in strength due to drying is generally found only in small pieces. This is due to the difficulty of drying larger pieces through to the center and to the weakening effect of checks which frequently occur in drying.

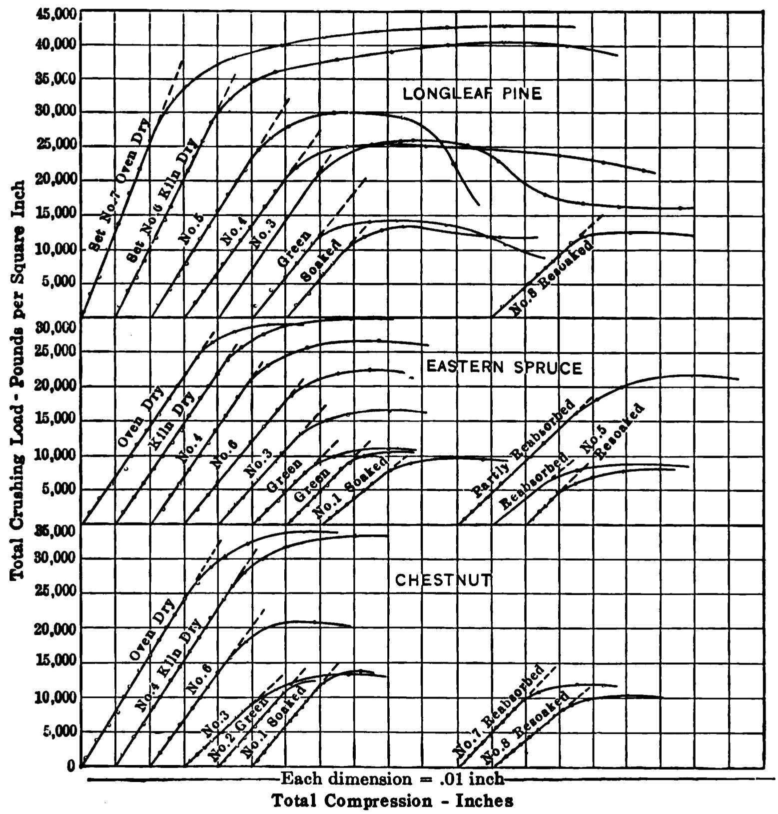


FIG. 14.—Relation between amount of compression and crushing load in pieces varying from an oven-dry to a soaked condition. (Compression parallel to grain—pieces 1½" × 1½" × 5¾").

EFFECT OF PRESERVATIVE AND CONDITIONING TREATMENTS

Wood-preserving processes may be divided into two classes—superficial processes and impregnation processes. In superficial processes, the liquid preservative is applied to the wood by a brush or by dipping; in impregnation processes the preservative is forced into the wood under pressure. The wood to be treated (ties, piling, structural timber, etc.) is placed in large steel cylinders; the cylinders are then tightly closed, and the preservative is run in through pipes. When the cylinders are full of preservative, pressure is applied and the preservative is thus forced into the wood. Sometimes it is difficult to force a sufficient amount of preservative into the timber under treatment and in such cases the wood is steamed before treatment to render it more permeable. Boiling in the preservative is also practiced. The impregnation processes,[1] the effect of which is considered here, are those in which steaming and boiling are used.

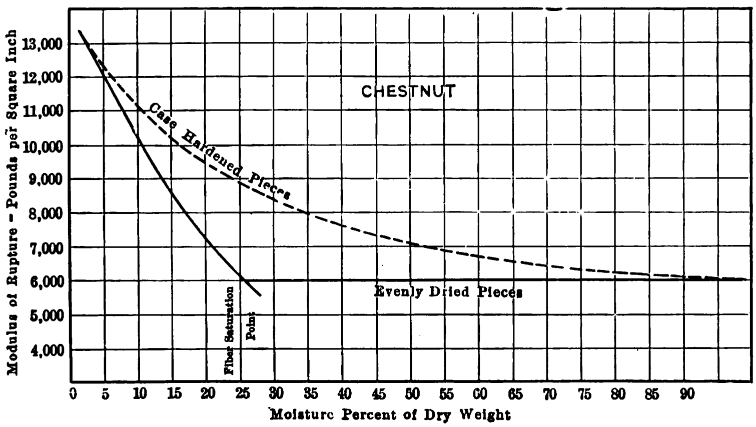


FIG. 15.—Effect of casehardening upon the form of the moisture-strength curve in bending tests. The upper curve is from casehardened specimens, the lower curve from uniformly dried specimens.

The preservative generally used is creosote, an oil derived from the distillation of coal tar.

TESTS ON TREATED SOUTHERN YELLOW PINE AND DOUGLAS FIR

A series of tests was conducted by the Forest Service over a period of several years to find the effect of commercial creosote treatments on the strength of southern yellow pine and Douglas fir stringers. To show this effect a comparison was made between the strength of treated and untreated stringers of the same size and quality. The stringers of both species were 8×16 inches in section and from 28 to 32 feet in length. The sticks were

[1] For a full description of the various processes, see "The Preservation of Structural Timber," by H. F. Weiss.

sorted in pairs with the object of having the sticks in each pair as much alike as possible. At the time of treatment each stick was cut into two stringers of equal length, making four test stringers in each group, two butt cuts and two second or top cuts. In order to neutralize the variation in strength between butt and top cuts the butt ends were treated in one group and the top ends in the next, and so on. Figure 16 shows the method of cutting the test material. One stringer in each group was treated while green and tested; one was tested green; one was treated, seasoned, and tested; and one was seasoned and tested. In this way the relative strength of the treated and natural material, both green and after seasoning, was shown.

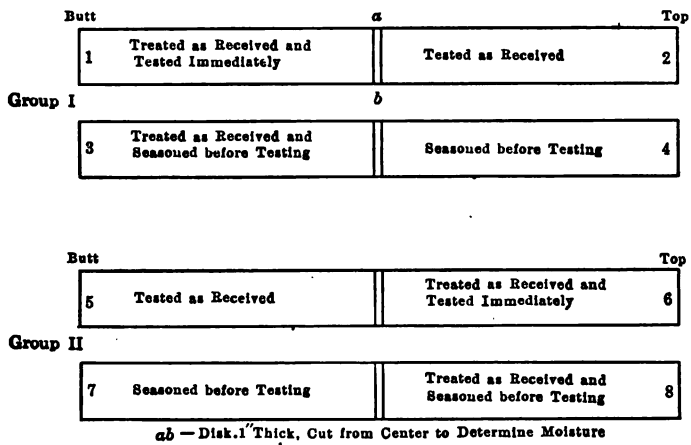


FIG. 16.—Method of cutting and marking test material.

The southern yellow pine stringers were of two kinds, longleaf pine and loblolly pine. The longleaf pine stringers were high grade timber and the loblolly pine stringers less valuable. The latter contained about 30 per cent. sapwood. The Douglas fir stringers included three grades.[1] It is customary to use only timbers of the two higher grades in permanent structures. Two processes of treatment were used with Douglas fir, the "boiling" process and the "steaming" process.

Methods of Treatment.—The preservative treatments to which the three species of structural timber were subjected were briefly as follows:

[1] Select, Merchantable, and Common as classified by the grading rules of the West Coast Lumber Manufacturers' Association, now the West Coast Lumbermen's Association.

Loblolly Pine.[1]—Steamed for four hours under 29 pounds pressure; vacuum of 26 inches applied for one hour; cylinder filled with creosote and pressure of 125 pounds applied for four and one-half hours at a temperature of 140° F.; vacuum of 23½ inches applied for one-fourth hour. Absorption of oil, 13½ pounds per cubic foot of wood.

Longleaf Pine.[2]—Steamed for six hours at 30 pounds pressure; vacuum of 26 inches applied for one hour; cylinder filled with creosote and pressure of 128 pounds applied for five and one-half hours at a temperature of 140° F. Absorption, 12¾ pounds per cubic foot of wood.

Douglas Fir.[2]—Boiling process. Boiled in creosote, for twenty-one and three-fourths hours at temperature of 215° F., loss of moisture during boiling, 1.2 pounds per cubic foot of wood; pressure raised from 0 to 145 pounds per square inch in five and three-fourths hours; temperature about 190° F. Absorption of oil, 11.2 pounds per cubic foot of wood, as determined by measuring tank readings.

Douglas Fir.—Steaming Process. Steamed at 90 pounds pressure per square inch for four and one-fourth hours; temperature about 325° F.; vacuum of 20 inches applied for eighteen and one-half hours; temperature 220° F. at end of period; cylinder filled with oil and pressure raised from 0 to maximum pressure of 140 pounds per square inch; pressure period, two and one-fourth hours, temperature of the oil, about 208° F. Absorption, 31 pounds per cubic foot of wood, as figured from increase in original weight of stringers. The stringers were not weighed after steaming, so that the probable loss can not be taken into account in computing the absorption.

Methods of Test.—The stringers were tested in bending by supporting them at the ends and applying the load at two points located one-third of the span from each of the end supports. This system corresponds closely to conditions of practice. In testing the beams the load was applied gradually and a record kept of the deflections corresponding to regular load increments.[3]

After failure occurred in the stringers, small pieces 2 × 2 inches in section and 30 inches in length were cut from the unbroken portions. These pieces were selected free from defects and with straight grain. Their location in a cross section of the stringer was noted, so that data could be secured on the relative strength of the inner and outer portions. The tests of small pieces included bending, compression parallel to grain,[3] compression perpendicular to grain,[3] and shearing.[3]

Results of Tests.—The results of the tests on the natural and treated stringers are shown in Table 4.[4] Table 5 gives the

[1] Run made March 4, 1908.

[2] Run made March 5, 1908.

[3] For method of test, see Chapter II.

[4] The tests on Douglas fir treated by the steaming process and seasoned are not yet completed.

TABLE 4.—STRENGTH AND STIFFNESS OF NATURAL AND TREATED STRINGERS

Species and condition	Rings per inch		Summerwood (per cent.)		Sapwood (per cent. volume)		Moisture (per cent.)		Modulus of rupture (pounds per square inch)		Modulus of elasticity (1000 pounds per square inch)		Fiber stress at elastic limit (pounds per square inch)		Shearing stress at maximum load (pounds per square inch)	
	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.
Longleaf pine:																
Partially air dry, 10 tests—																
Average	14.2	14.0	38.8	38.8	5	2	27.6	26.2	5,151	5,132	1,409	1,275	3,346	2,898	408	309
Maximum	17.0	15.5	50.0	54.3	21	11	29.1	30.3	5,575	5,830	1,617	1,462	4,180	3,970	438	452
Minimum	10.8	11.3	28.0	29.3	0	0	25.9	22.1	4,150	4,600	1,235	1,113	2,390	2,050	325	357
Air dry, 10 tests—																
Average	19.2	18.0	38.2	41.6	11	10	19.0	21.8	6,466	6,376	1,561	1,471	4,950	4,762	499	499
Maximum	23.0	19.7	45.3	44.0	21	17	19.6	23.4	8,600	7,620	1,767	1,742	6,040	5,530	658	595
Minimum	17.3	16.3	33.3	38.7	3	2	18.4	21.1	4,280	5,260	1,236	1,227	3,450	3,740	320	408
Loblolly pine:																
Partially air dry, 10 tests—																
Average	5.8	5.9	43.2	43.2	8	14	35.7	49.4	4,858	4,150	1,296	1,155	2,738	2,080	402	339
Maximum	7.3	7.3	52.5	46.0	22	35	54.1	70.2	6,440	4,960	1,515	1,234	3,250	2,340	535	409
Minimum	4.8	4.3	36.8	35.8	0	0	24.1	36.0	3,680	3,390	1,089	1,030	2,160	1,830	301	275
Air dry, 10 tests—																
Average	6.8	7.3	34.5	37.2	40	40	18.2	23.8	6,392	5,380	1,534	1.297	4,806	3,808	507	437
Maximum	10.3	12.3	40.0	45.0	78	70	18.8	29.6	7,680	6,270	1,596	1,367	5,430	4,580	624	509
Minimum	3.7	3.7	33.0	30.3	7	5	17.5	18.7	4,501	4,360	1,430	1,238	3,910	3,520	362	361
Douglas fir:																
Boiling process—																
Green, 40 tests—																
Average	11.0	11.2	45.2	45.4	0	0	33.6	28.5	5,690	3,820	1,569	1,542	3,980	2,980	381	253
Maximum	17.7	19.0	57.0	61.0	..	..	38.5	32.8	7,590	5,540	2,070	2,001	5,340	4,850	514	364
Minimum	4.7	5.4	35.0	37.0	..	..	28.3	24.3	4,120	2,090	2,115	1,028	1,950	1,370	277	137
Air dry, 38 tests—																
Average	11.5	11.3	39.5	38.2	0	0	15.3	19.5	6,240	3,860	1,809	1,560	4,560	2,840	407	254
Maximum	18.5	19.6	52.0	47.0	..	..	17.8	23.0	9,440	4,930	2,402	2,062	6,630	4,010	615	324
Minimum	6.6	6.2	30.0	31.0	..	..	13.4	16.4	3,990	2,510	1,400	1,252	3,750	1,360	256	165
Steaming process—																
Green, 30 tests—																
Average	14.7	14.0	36.6	34.2	0	0	37.5	33.0	5,430	3,540	1,557	1,412	3,740	2,370	366	237
Maximum	22.2	20.9	53.8	50.0	..	..	45.9	36.8	6,710	5,740	1,945	1,778	4,560	3,930	454	384
Minimum	5.9	5.1	26.3	27.5	..	..	32.4	29.3	4,280	2,310	1,277	1,195	2,730	1,490	291	150
Air dry—tests—																
Average	....	....	....	....	..	..	....	....	.....	.....	.....	.....	.....	.....	...	...
Maximum	....	....	....	....	..	..	....	....	.....	.....	.....	.....	.....	.....	...	...
Minimum	....	....	....	....	..	..	....	....	.....	.....	.....	.....	.....	.....	...	...

TABLE 5.—STRENGTH AND STIFFNESS OF SMALL PIECES—NATURAL AND TREATED—CUT FROM THE INSIDE AND OUTSIDE PORTIONS OF LONGLEAF PINE, LOBLOLLY PINE, AND DOUGLAS FIR STRINGERS

Species, condition, and locality	Number of tests		Moisture (per cent.)		Rings per inch		Modulus of rupture (pounds per square inch)		Fiber stress at elastic limit (pounds per square inch)		Modulus of elasticity (1000 pounds per square inch)	
	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.	N.	T.
Longleaf pine:												
Partially air dry—												
All	28	29	21.5	....	19.2	18.3	9,507	9,036	5,623	5,365	1,493	1,434
Outside	24	24	21.0	....	19.6	19.3	9,455	9,046	5,587	5,376	1,485	1,428
Inside	4	5	24.6	....	14.6	14.4	9,978	8,870	5,953	5,088	1,581	1,464
Air dry—												
All	23	23	12.8	....	19.9	19.6	13,520	11,418	8,070	6,824	1,663	1,508
Outside	18	17	13.0	....	20.2	18.1	13,109	11,208	8,060	6,855	1,641	1,489
Inside	5	6	12.6	....	18.5	14.2	14,378	11,495	8,153	9,543	1,714	1,527
Loblolly pine:												
Partially air dry—												
All	30	28	20.3	....	6.4	6.4	8,605	6,571	5,109	3,531	1,350	1,104
Outside	24	22	19.8	....	6.9	6.9	8,599	6,221	5,120	3,294	1,339	1,086
Inside	6	6	22.2	....	4.6	5.5	8,592	8,148	5,010	4,560	1,365	1,289
Air dry—												
All	30	26	12.0	....	7.2	7.4	12,491	12,182	7,502	7,611	1,605	1,603
Outside	24	21	12.0	....	7.6	7.6	12,382	12,122	7,434	7,644	1,607	1,609
Inside	6	5	11.8	....	5.7	5.8	13,003	12,157	7,713	7,145	1,595	1,550
Douglas fir:												
Boiling process—												
Green—												
All	48	38	30.1	27.5	10.7	12.6	7,923	6,216	4,450	3,434	1,595	1,486
Outside	24	19	29.6	....	11.7	13.9	8,041	6,862	4,407	3,897	1,617	1,570
Inside	24	19	30.6	....	9.6	11.4	7,805	5,571	4,493	2,971	1,583	1,401
Air dry—												
All	66	54	15.6	....	13.2	13.1	10,608	6,598	6,546	4,003	1,778	1,624
Outside	33	27	14.8	....	14.1	13.6	10,929	6,721	6,953	4,021	1,787	1,617
Inside	33	27	16.4	....	12.2	12.6	10,287	6,475	6,138	3,985	1,770	1,632
Steaming process—												
Green—												
All	..	..	....	....	....	....	......	......	.....	.....	.....	.....
Outside	..	..	....	....	....	....	......	......	.....	.....	.....	.....
Inside	..	..	....	....	....	....	......	......	.....	.....	.....	.....
Air dry—												
All	..	..	....	....	....	....	......	......	.....	.....	.....	.....
Outside	..	..	....	....	....	....	......	......	.....	.....	.....	.....
Inside	..	..	....	....	....	....	......	......	.....	.....	.....	.....

results of tests on small pieces cut from the uninjured portions of the stringers after test.

Stringers.—The values for modulus of rupture (bending strength) and modulus of elasticity (stiffness) for the natural and treated stringers in each group are compared in Figs. 17, 18, 19, 20, and 21 for loblolly pine, longleaf pine, and Douglas fir. The diagrams were made by first plotting the values for modulus of rupture of the natural beams (solid lines) arranged

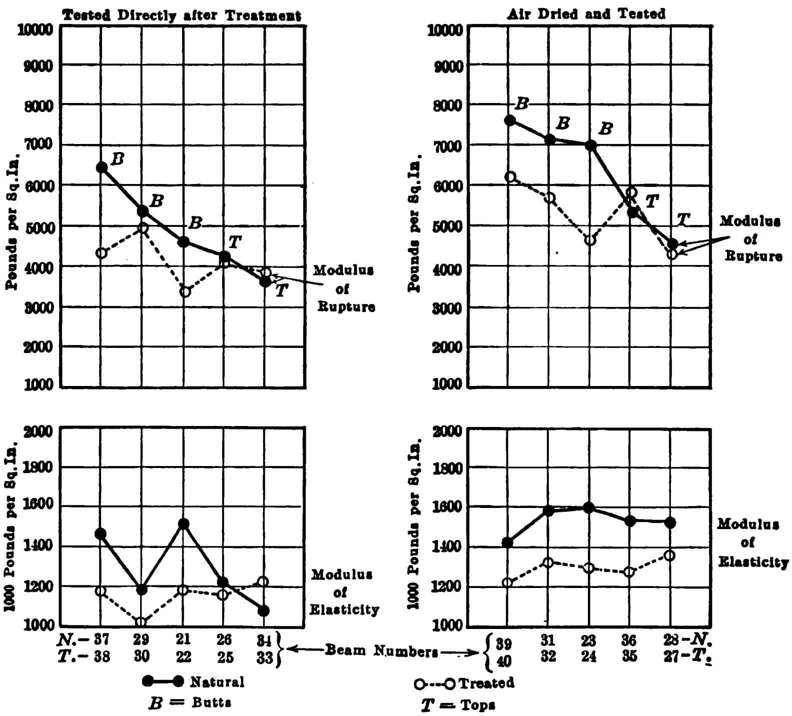


FIG. 17.—Effect of preservative treatment on the strength and stiffness of loblolly-pine stringers treated partially air dry.

from the highest to the lowest, beginning with the highest value on the left. The modulus of rupture of the treated half of the test pieces (dotted lines) was then plotted on the same vertical line as the untreated pieces. The modulus of rupture values for the natural beams are marked (B) or (T) to show whether they are butts or tops. The values for modulus of elasticity for the same beams are plotted in the lower part of the diagrams. All values for the same beam are in the same vertical line.

Loblolly Pine.—Figure 17 shows that when the butts were treated the breaking strength of the butts and tops of the loblolly pine stringers fell rather close together, while when the tops were treated the breaking strength values were much farther apart. This shows a weakening due to the treatment even considering the lower breaking strength of the top stringers. The tests are too few to form a basis for definite conclusions. The

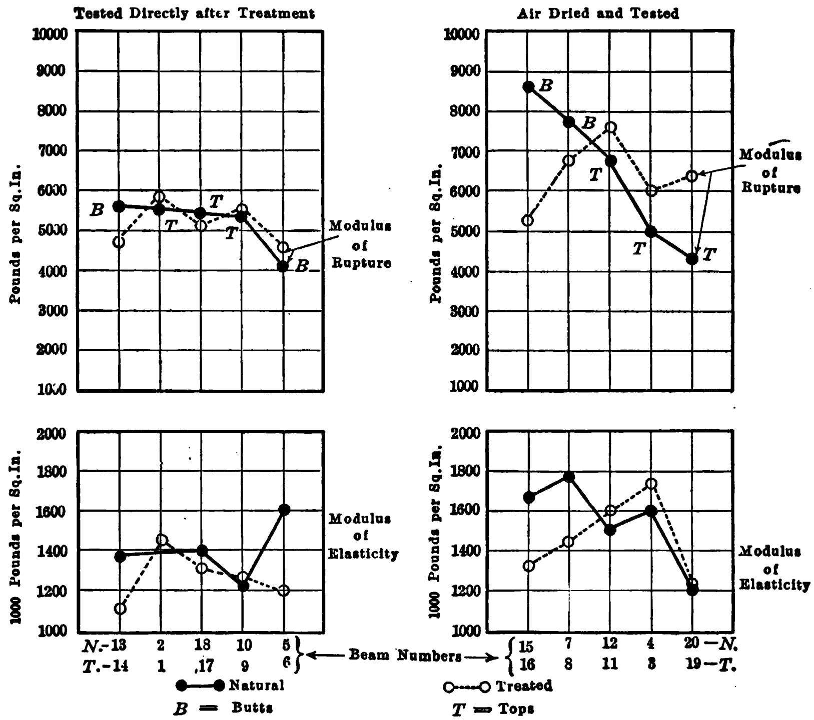


FIG. 18.—Effect of preservative treatment on the strength and stiffness of longleaf-pine stringers treated partially air dry.

amount of weakening due to the treatment was probably not above 17 per cent. The stiffness shows a greater weakening due to treatment than does the breaking strength. Both treated and untreated stringers showed a strength about 30 per cent. greater in the seasoned material than in the material tested directly after treatment.

Longleaf Pine.—Figure 18 shows that the breaking strength of the longleaf pine stringers was apparently unaffected by the treatment used. There was a slight reduction in the stiffness. In the air seasoned beams the untreated butt cuts were higher in strength and stiffness than the treated top cuts; but on the other hand, the untreated top cuts fell below the treated butts in strength and stiffness in nearly every case. In the stringers tested immediately after treatment, there is less variation between the treated and untreated material.

Douglas Fir.—Figures 19 and 20 indicate a marked weakening in the breaking strength of the Douglas fir stringers treated by the so-called "boiling" process as used in this case. The average

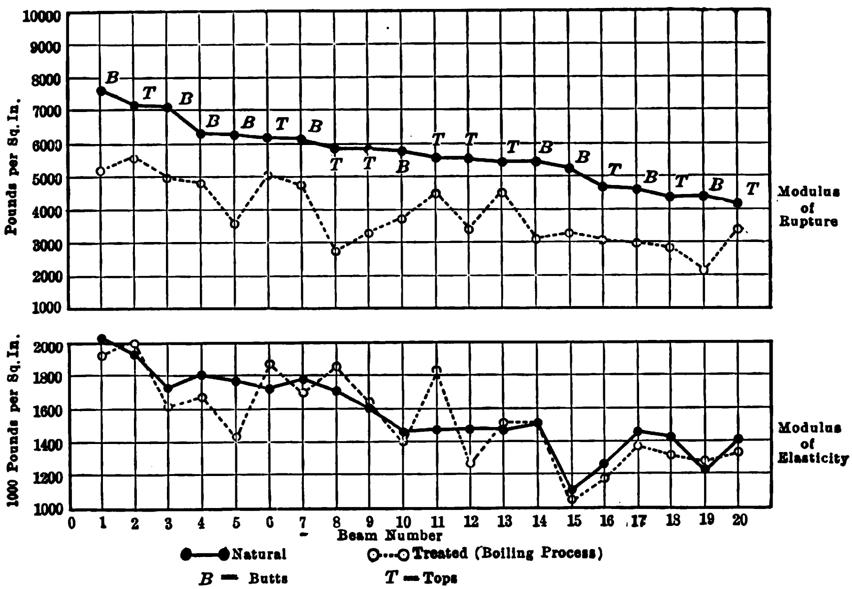


FIG. 19.—Effect of "boiling process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green and tested without seasoning.

breaking strength of the treated stringers tested green and after seasoning is 33 per cent. and 39 per cent., respectively, less than the average strength of the natural stringers. In the green material no weakening is apparent in the stiffness. The seasoned stringers, however, show a falling off in stiffness in the treated material.

Figure 21 shows the strength and stiffness of green Douglas fir treated by the so-called "steaming" process and similar natural stringers. The breaking strength was considerably less in the treated material (35 per cent.), and the stiffness was slightly less.

Small Pieces Cut from Stringers.—Table 5 shows that the sticks cut from the treated loblolly and longleaf pine stringers are in general weaker than those cut from the natural stringers, but the difference is slight except for partially air dry loblolly pine. Part of the apparent loss in strength of the treated material may be ascribed to its higher moisture content indicated by determinations for moisture in various parts of the cross sections of the treated timbers of these two species.

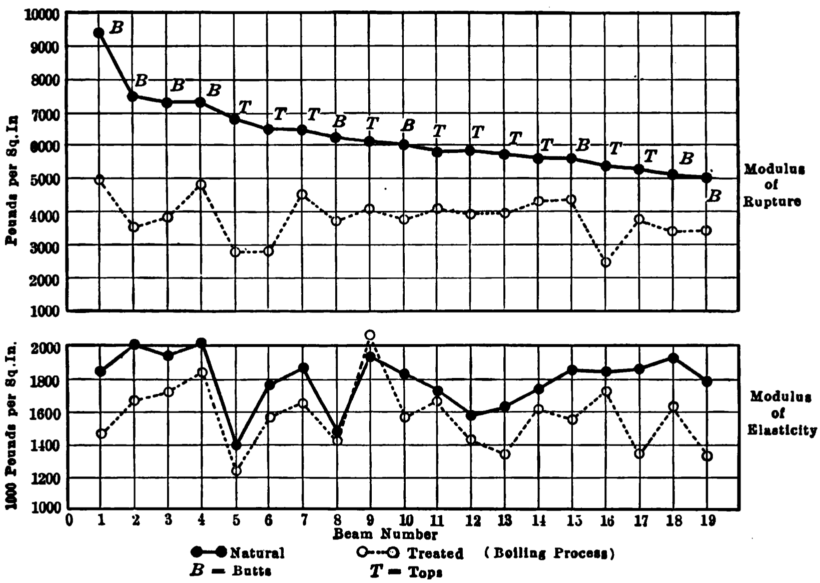


FIG. 20.—Effect of "boiling process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green, air seasoned and tested.

In the Douglas fir treated by the boiling process and tested green, the average (Table 5) for the outside sticks shows a decrease in strength over the natural, with but little difference in stiffness. As compared with the natural sticks, the treated sticks cut from the interior of the main beams showed a more marked drop in strength and stiffness. The air dry material in all cases showed a decided decrease in the strength of the treated sticks. The decrease in stiffness was less marked. Part of this decrease may be accounted for by the higher moisture content of the treated pieces.

Special Tests on Small Pieces.—Table 6 gives a condensed summary of the results of a series of tests on small clear specimens (2 by 2 inches in section) of Douglas fir, longleaf pine, and shortleaf pine made to study the effect of the various steps used in the treatment of the full sized stringers. Eight sticks were subjected to each of the processes shown in Table 6. One-half of the sticks were tested shortly after treatment and one-

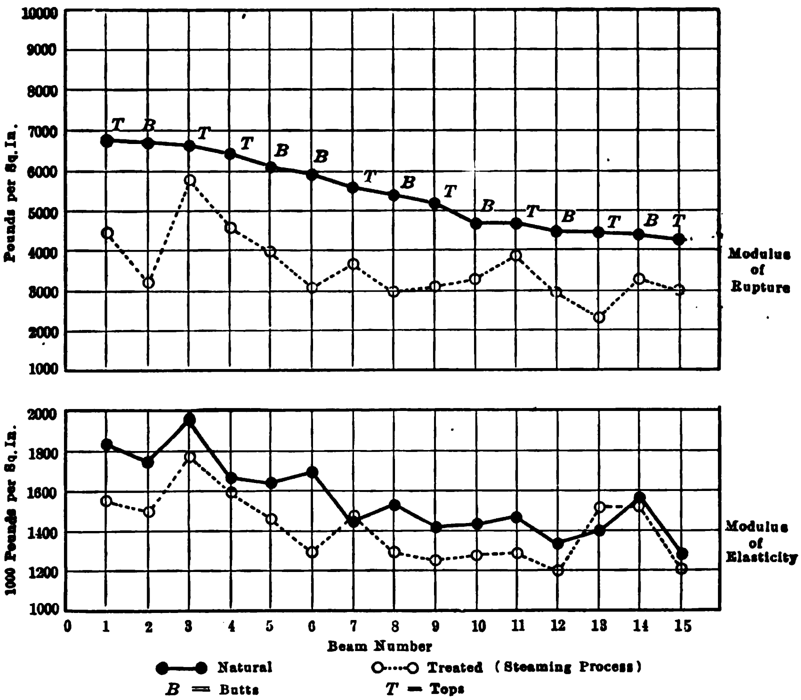


FIG. 21.—Effect of "steaming process" of preservative treatment on the strength and stiffness of Douglas-fir stringers treated green and tested without seasoning.

half after they had been piled in the laboratory long enough (5 months) to reach a practically constant weight.

All the processes caused a reduction in the strength values of the unseasoned material of the three species with, in most cases, a recovery after seasoning, except in the tension tests. In these the weakening in the unseasoned material remained after seasoning in all processes but the creosote bath (next to last column).

The shrinkage measurements on the steamed material, with

TABLE 6.—EFFECT OF VARIOUS TREATMENTS ON SMALL, CLEAR STICKS (RESULTS EXPRESSED[1] IN PER CENT. OF STRENGTH OF UNTREATED MATERIAL)

	Steamed at 20 pounds 5 hours		Steamed at 20 pounds 5 hours; 26-inch vacuum 1 hour		Steamed at 20 pounds 5 hours; 26-inch vacuum 1 hour; creosote, 120 pounds pressure, 4½ hours		Creosote bath at atmospheric pressure, 200° F., 27 hours		Creosote bath at atmospheric pressure, 200° F., 27 hours; creosote at 145 pounds pressure, 180° F., 1¾ hours	
	Unseasoned	Air dry	Unseasoned	Air dry	Unseasoned	Air dry	Unseasoned	Air dry	Unseasoned	Air dry
Bending:										
Modulus of rupture—										
Douglas fir	74	96	78	93	83	86	92	89	86	98
Longleaf pine	83	100	.....	.....	80	85	.....	.....	81	93
Shortleaf pine	73	107	72	98	84	104	96	108	89	103
Modulus of elasticity—										
Douglas fir	87	100	84	100	95	98	97	105	93	99
Longleaf pine	94	106	.....	.....	91	99	.....	.....	92	108
Shortleaf pine	84	104	92	103	96	105	112	102	96	100
Compression:										
Maximum crushing strength—										
Douglas fir	68	102	76	88	80	97	83	102	90	112
Longleaf pine	79	102	.....	.....	82	76	.....	.....	80	87
Shortleaf pine	70	101	71	101	82	104	89	103	89	109
Shear with grain—										
Douglas fir	72	93	74	96	74	100	91	118	86	125
Longleaf pine	77	118	.....	.....	73	.....	.....	.....	74	115
Shortleaf pine	71	107	74	105	80	108	88	114	90	115
Tension perpendicular to grain—										
Douglas fir	57	69	54	64	48	57	47	116	63	117
Longleaf pine	42	47	.....	.....	60	.....	.....	.....	61	67
Shortleaf pine	70	81	71	73	71	64	95	130	79	88
Shrinkage[1] in cross section during treatment—										
Douglas fir	0.13	.....	0.83	.....	3.34	.....	0.73	.....	9.33	
Longleaf pine	0.42	.....	.....	.....	0.08	.....	.....	.....	0.66	
Shortleaf pine	0.33	.....	0.50	.....	0.92	.....	0.25[2]	.....	0.75	
Shrinkage in cross section during treatment and seasoning—										
Douglas fir	.....	8 58	.....	8.35	.....	7.39	.....	7.46	.....	11.31
Longleaf pine	.....	10.64	.....	.....	.....	6.18	.....	.....	.....	7.90
Shortleaf pine	.....	10.47	.....	9.30	.....	5.94	.....	7.50	.....	5.73

[1] Shrinkage given in per cents. of areas when first measured. Corresponding shrinkage of untreated material, green to air-dry condition; Douglas fir, 6.40; longleaf pine, 8.48; shortleaf pine, 7.29.
[2] Increase in volume.

and without vacuum, showed less than 1 per cent. decrease in volume during treatment for all the species. After seasoning, a shrinkage of from 8.4 per cent. for Douglas fir to 10.6 per cent. for longleaf pine was recorded. Steaming and vacuum followed by creosoting showed a somewhat higher shrinkage for Douglas fir than for the pines, both in the unseasoned and air dry pieces. The creosote bath had little influence on the shrinkage, the reduction after seasoning corresponding closely to the shrinkage of untreated pieces. The pressure treatment following the creosote bath showed a somewhat higher shrinkage for Douglas fir than for longleaf or shortleaf pine.

While the series of special tests does not explain the weakening in the Douglas fir stringers, it indicates that the trouble has to do with stresses in the full sized stringers, probably caused by rapid and unequal shrinkage during the process.

Deductions.—1. Timber may be very materially weakened by preservative processes.

2. Creosote in itself does not appear to weaken timber.

3. A preservative process which will seriously injure one timber may have little or no effect on the strength of another.

4. A comparison of the effect of a preservative process on the strength of different species should not be made, unless it is the common or best adapted process for all the species compared.

5. The same treatment given to a timber of a particular species may have a different effect upon different pieces of that species, depending upon the form of the timber used, its size, and its condition when treated.

CHAPTER IV

STRENGTH OF WOODEN PRODUCTS

Structural Timbers—Strength of the Principal Structural Species—Characteristics Affecting the Strength of Timbers—Characteristics Affecting Decay in Timbers—Relations Indicated by Tests—The Grading of Structural Timbers—Classification of Defects—Examples of Commercial Specifications and Grading Rules for Structural Timbers—Working Stresses—Telephone Poles—Cross Arms—Packing Boxes—Compression and Drop Tests—Tests by a Revolving Drum Machine—Wooden Vehicle Parts—Spokes—Shafts—Axles—Poles—Deductions from Tests

The value of certain qualities in wood depends on the use to which the wood is put. Properties which are absolutely essential for one use may be of no particular importance for another. Tests on wooden products serve to show not only the suitability of different species for certain uses but also the strongest forms of the product.

The following tests on structural timbers, telegraph poles, cross arms, packing boxes, and vehicle parts were made to compare proposed substitutes with material considered standard or to determine the possibility of improving standard forms so as to obtain a more satisfactory product with the same or a smaller amount of material. In all tests of this kind the conditions met with in commercial use were duplicated as nearly as possible.

STRUCTURAL TIMBERS

Strength of the Principal Structural Species

Tests on the strength of structural timbers furnish the basis (1) for determining the proper working stresses and factors of safety to use in the design of timber structures, (2) for studying

TABLE 7.—AVERAGE STRENGTH VALUES OF GREEN STRUCTURAL TIMBERS WITH ORDINARY DEFECTS AND SMALL SPECIMENS OF GREEN MATERIAL WITHOUT DEFECTS

Species	Bending					Compression parallel to grain	Compression perpendicular to grain	Shear
	Weight per cubic foot, oven dry (pounds)	Rings per inch	Fiber stress at elastic limit, pounds per square inch	Modulus of rupture, pounds per square inch	Modulus of elasticity, 1,000 pounds per square inch	Crushing strength at maximum load, pounds per square inch	Fiber stress at elastic limit, pounds per square inch	Shearing strength, pounds per square inch
Cypress:								
Structural sizes	....	....	....	....	....	....	...	...
Small specimens	32.2	25.0	4,430	7,110	1,378	3,960	548	818
Douglas fir:								
Structural sizes	28.0	11.0	3,968	5,983	1,517	3,495	570	...
Small specimens	....	....	5,227	8,280	1,597	4,030	...	765
Eastern hemlock:								
Structural sizes	....	....	....	....	....	....	...	...
Small specimens	28.0	20.5	4,155	6,685	1,124	3,270	497	877
Loblolly pine:								
Structural sizes	31.0	5.9	3,040	5,084	1,387	2,940	500	...
Small specimens	....	....	4,100	7,870	1,440	3,240	...	630
Longleaf pine:								
Structural sizes	34.1	16.7	4,015	6,191	1,600	....	495	....
Small specimens	35.1	16.5	5,270	8,330	1,530	4,285	570	1,048
Norway pine:								
Structural sizes	25.0	13.7	2,492	3,864	1,133	2,555	...	...
Small specimens	....	....	2,808	5,173	960	2,504	...	589
Red spruce:								
Structural sizes	25.5	21.9	2,394	3,566	1,180	....	...	...
Small specimens	....	21.3	3,627	5,900	1,157	2,750	310	758
Redwood:								
Structural sizes	22.0	18.8	3,760	4,472	1,042	3,882	434	...
Small specimens	....	....	4,750	6,980	1,061	3,980	539	742

Species	Bending					Compression parallel to grain	Compression perpendicular to grain	Shear
	Weight per cubic foot, oven dry (pounds)	Rings per inch	Fiber stress at elastic limit, pounds per square inch	Modulus of rupture, pounds per square inch	Modulus of elasticity, 1,000 pounds per square inch	Crushing strength at maximum load, pounds per square inch	Fiber stress at elastic limit, pounds per square inch	Shearing strength, pounds per square inch
Shortleaf pine:								
Structural sizes	30.0	12.1	3,237	5,548	1,473	3,435	351	...
Small specimens	....	....	4,350	7,710	1,395	3,570	400	704
Tamarack:								
Structural sizes	30.0	14.0	2,813	4,556	1,220	3,230	...	...
Small specimens	....	....	3,875	6,820	1,141	3,190	...	668
Western hemlock:								
Structural sizes	27.0	15.6	3,516	5,296	1,445	3,355	434	...
Small specimens	....	....	4,406	7,294	1,428	3,392	...	630
Western larch:								
Structural sizes	28.0	24.3	3,324	4,948	1,301	3.510	456	...
Small specimens	....	....	4,274	7,251	1,310	3.696	...	700
Western yellow pine:								
Structural sizes	30.8	15.6	2,769	4,560	1,243	2,830	299	...
Small specimens	25.6	14.9	3,156	5,831	1,178	2,896	...	...
White spruce:								
Structural sizes	21.3	9.3	2,239	3,288	1,081	....	...	...
Small specimens	....	10.2	3,090	5,185	998	2,370	270	651

the relation of the physical characteristics and defects of timber to its strength, and (3) for preparing grading rules and specifications for various forms of structural timbers.

Table 7 shows average strength values for a number of the principal structural species.[1] The averages for the bending tests are the results of tests on unseasoned timbers ranging from 4×10 inches to 8×16 inches in cross section for the structural sizes, and of tests on small (2″×2″×30″) specimens (cut from large beams after test) free from defects.

Many publications dealing with timber give results of tests made only on small, clear, seasoned specimens. Such values may be from one and one-half to two times as high as similar values from tests on large timbers and joists containing the ordinary defects. In applying to commercial material values derived from tests care should be taken to see that the commercial timber is of the same quality as the test timber or that the proper adjustments are made in the test values so that they may accurately represent the material in question.

The two qualities of greatest value in the wood of structural timber are strength and durability. In order properly to select material for a given use, a knowledge of the influence which the visible characteristics of timber have on these two qualities is necessary.

Characteristics Affecting the Strength of Timber

The characteristics to be considered in judging the strength of timber are density of wood, direction of grain, rate of growth, moisture condition, proportion of sapwood, size and condition of defects, such as knots, checks, and shakes, and the position of the pith in the cross section.

Density.—The strength, hardness, shock-resisting ability and stiffness of wood vary with its weight when the wood is in the form of small, clear, straight-grained pieces of the same moisture content. The relation of bending strength to dry weight for a single species (longleaf pine) is shown in Fig. 22. In this figure each point represents a single test, the location of the point being determined by the bending strength (modulus of rupture) and

[1] For a more complete discussion see Forest Service *Bulletin* 108, "Tests of Structural Timbers."

SPECIES TEST
LOCALITY OF GR

HARDWOODS

SPECIES	LOCALITY
ALDER	WASH.
ASH, BILTMORE	TENN.
" BLACK	MICH.
" BLACK	WIS.
" BLUE	KY.
" GREEN	LA.
" GREEN	MO.
" PUMPKIN	MO.
" WHITE	ARK.
" WHITE	N. Y.
" WHITE	W. VA.
ASPEN	WIS.
ASPEN, LARGE TOOTH	WIS.
BASSWOOD	PA.
BASSWOOD	WIS.
BEECH	IND.
BEECH	PA.
BIRCH, PAPER	WIS.
" SWEET	PA.
" YELLOW	PA.
" YELLOW	WIS.
BUCKEYE, YELLOW	TENN.
BUTTERNUT	TENN.
BUTTERNUT	WIS.
CHERRY, BLACK	PA.
CHERRY, WILD RED	TENN.
CHESTNUT	MD.
CHESTNUT	TENN.
COTTONWOOD, BLACK	WASH.
CUCUMBER TREE	TENN.
DOGWOOD (FLOWERING)	TENN.
ELM, CORK	WIS., MARATHON C
" CORK	WIS., RUSK CO.
" SLIPPERY	IND.
" SLIPPERY	WIS.
" WHITE	PA.
" WHITE	WIS.
GUM, BLACK	TENN.
" BLUE (EUCALYPTUS)	CAL.
" COTTON	LA.
" RED	MO.
HACKBERRY	IND.
HACKBERRY	WIS.
HAW, PEAR	WIS.
HICKORY, BIG SHELLBARK	MISS.
" BIG SHELLBARK	OHIO.
" BITTERNUT	OHIO.
" MOCKERNUT	MISS.
" MOCKERNUT	PA.
" MOCKERNUT	W. VA.
" NUTMEG	MISS.
" PIGNUT	MISS.
" PIGNUT	OHIO.
" PIGNUT	PA.
" PIGNUT	W. VA.
" SHAGBARK	MISS.
" SHAGBARK	OHIO.
" SHAGBARK	PA.
" SHAGBARK	W. VA.
" WATER	MISS.
HOLLY, AMERICAN	TENN.
HORNBEAM	WIS.
LAUREL, MOUNTAIN	TENN.
LOCUST, BLACK	TENN.
LOCUST, HONEY	IND.
MADRONA	CAL.
MAGNOLIA	LA.
MAPLE, OREGON	WASH.
" RED	PA.
" RED	WIS.
" SILVER	WIS.
" SUGAR	IND.
" SUGAR	PA.
" SUGAR	WIS.
OAK, BUR	WIS.
" CALIFORNIA BLACK	CAL.
" CANYON LIVE	CAL.
" CHESTNUT	TENN.
" COW	LA.
" LAUREL	LA.
" POST	ARK.
" POST	LA.
" RED	ARK.
" RED	IND.
" RED	LA.
" RED	TENN.
" SPANISH HIGHLAND	LA.
" SPANISH LOWLAND	LA.
" SWAMP WHITE	IND.
" TANBARK	CAL.
" WATER	LA.
" WHITE	ARK.
" WHITE	IND.
" WHITE	LA., RICHLAND PAR
" WHITE	LA., WINN PARISH
" WILLOW	LA.
" YELLOW	ARK.
" YELLOW	WIS.
OSAGE ORANGE	IND.
POPLAR, YELLOW	TENN.
RHODODENDRON, GREAT	TENN.
SASSAFRAS	TENN.
SERVICEBERRY	TENN.
SILVERBELL TREE	TENN.
SOURWOOD	TENN.
SUMACH, STAGHORN	WIS.
SYCAMORE	IND.
SYCAMORE	TENN.
UMBRELLA, FRASER	TENN.
WILLOW, BLACK	WIS.
WITCH HAZEL	TENN.

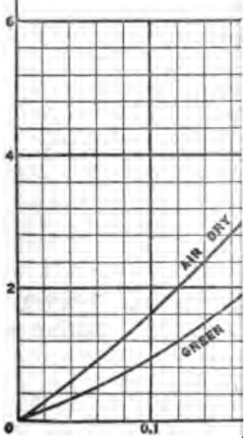


Fig. 23.—

the dry weight (specific gravity) of the piece tested. The greater strength of the heavier pieces is evident.

The relation of bending strength to dry weight for 113 different species is shown in Fig. 23. In this figure each small circle represents an average of about 60 tests made on five typical trees cut in one locality. The circles are located according to the average bending strength (modulus of rupture) and the average specific gravity of each group of tests. The solid circles

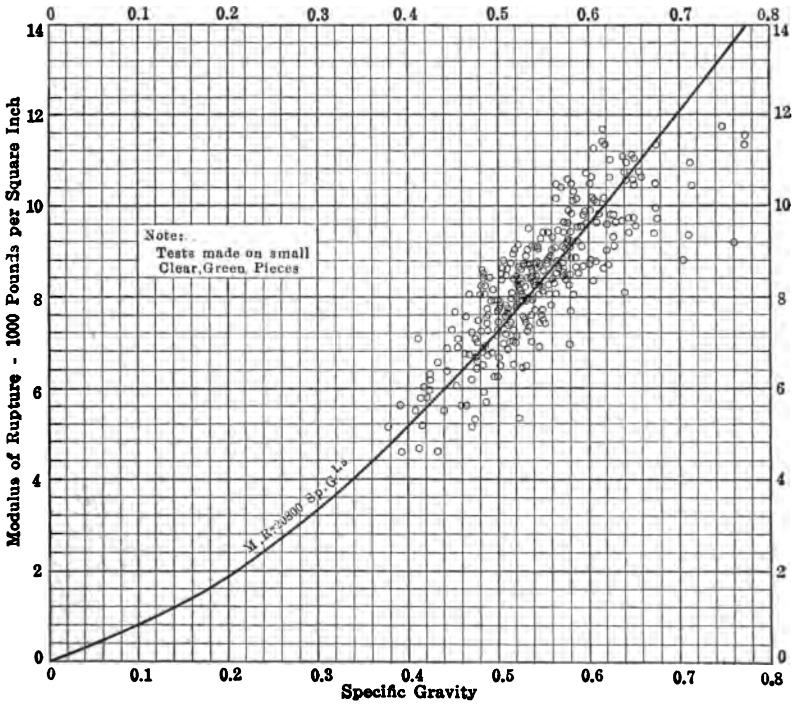


FIG. 22.—Relation between bending strength and dry weight for longleaf pine.

are for green material and the open circles for air dry material. The numbers show the species and locality of growth. For example, the solid circle 3 shows the bending strength of green Engelmann spruce cut in San Miguel County, Colorado, and the open circle 3 shows the bending strength of air dry pieces cut from the same trees. Figure 23 shows that the heavier species tested had the greater average bending strength. From Figs. 22 and 23 it is evident that as the weight increases the strength increases both in the case of pieces all cut from the same kind of wood and in the case of average values of many different kinds of wood.

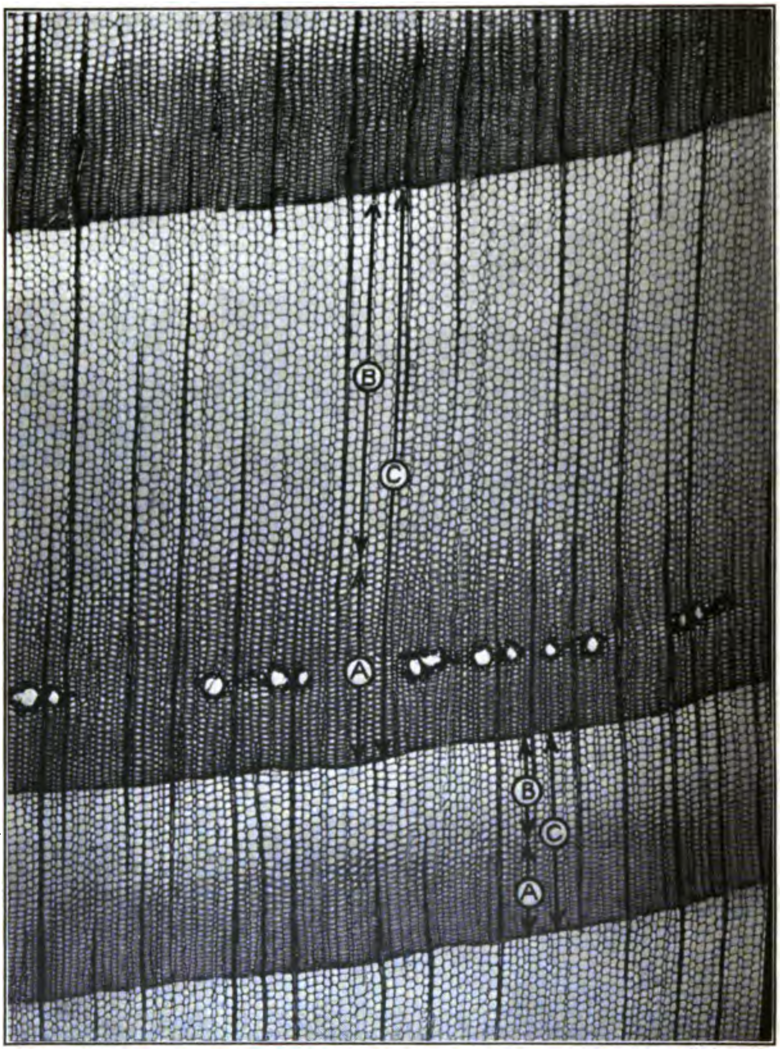


Fig. 24.—Douglas fir (magnified 50 times). *A*, summerwood; *B*, springwood; *C*, annual ring—one year's growth. Note porous springwood and denser summerwood.

In order to make use of this fact in grading timber, some way of estimating density from a visual inspection is necessary.

The character of the annual rings as shown on a cross section of the ends of a stick of timber furnishes a means of judging its strength. Wood is made up of concentric rings of growth. Each ring consists of two parts, springwood and summerwood. The springwood, as its name indicates, is formed first, and in the woods commonly used for structural purposes is the lighter-

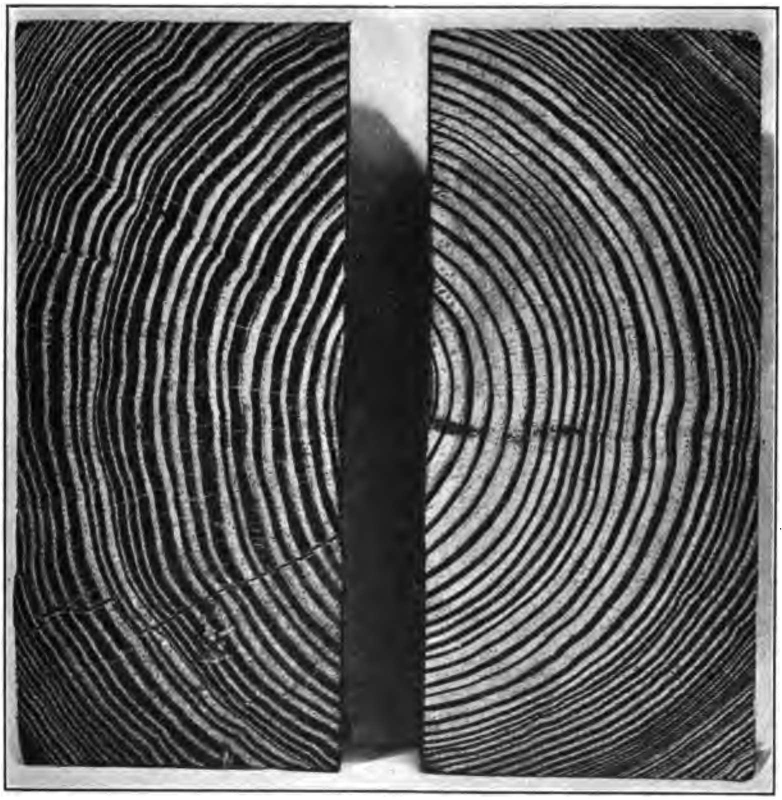


FIG. 25.—Cross section of loblolly-pine beams. Note different proportions of summerwood.

colored, softer part of the ring. The summerwood is built up later and is darker and denser (see Fig. 24). In certain woods the change from springwood to summerwood is distinctly marked, so that the proportion of summerwood in an annual ring or in a cross section can be closely estimated. Figure 25 shows the well-defined bands of summerwood and springwood in the ends of two loblolly pine beams. Summerwood is considerably heavier than springwood. A number of tests on small pieces of summerwood and springwood cut from wide-ringed loblolly pine showed a density and strength about twice as great in the summerwood as in the springwood. The proportion of summerwood in a cross section of a stick is therefore a means of estimating its density and strength. It should be remembered that density is the basic factor governing strength and that proportion of summerwood as a satisfactory indicator of strength is dependent on the difference in density of the two parts of the annual ring and on the closeness with which these parts can be differentiated.

Rate of Growth.—The rate of growth is generally spoken of in rings per inch. The average rate of growth is determined by counting the annual rings on a radial line on the cross section and dividing the number of rings by the length of the line in inches. In the case of some of the species tested it appears that there is a rate of growth which is generally associated with the greatest density and greatest strength. For a number of the species tested this is:

	Rings per inch
Douglas fir	24
Shortleaf pine	12
Loblolly pine	6
Western larch	18
Western hemlock	14
Tamarack	20
Norway pine	18
Redwood	30
Longleaf pine	10

However, density is the basic requisite for strength, and too much importance should not be given to the rates of growth as an indication of satisfactory material.

Abnormal rates of growth, either fast or slow, in structural timbers are frequently associated with material of low density, and timber with such growth should be regarded with suspicion. Very fast-grown wide-ringed timber is also comparatively difficult to work and frequently wears irregularly. The use of nails, spikes, and screws in wide-ringed timber may give trouble on account of the width of the alternate hard and soft bands in each annual ring.

Direction of Grain.—By grain is often meant the lines formed by cutting the rings of annual growth. If a stick is cut from a log in such a way that these lines run diagonally from one edge of the stick to the other instead of parallel to the edges, the load that it will carry as a beam will be considerably reduced, and, moreover, failure will be more complete when it occurs.

There is, however, another kind of cross grain, known as spiral grain, which is more difficult to detect than that just described, but which also weakens the timber and may cause unexpected complete failure; that is, a break in which the stick snaps in pieces. The wood of the conifers may be considered as built up mainly of elongated cells running lengthwise with the trunk, with a much smaller proportion of cells in small bundles located at right angles to

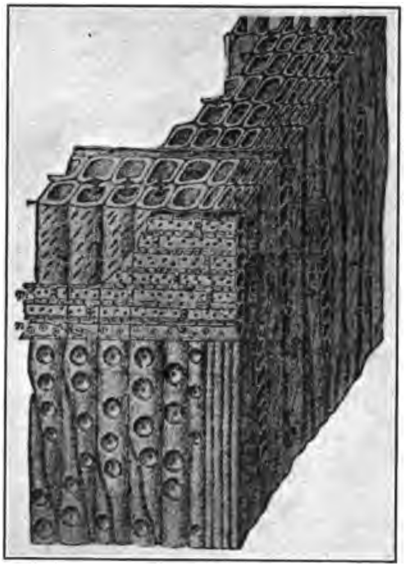


FIG. 26.—Wood of spruce (magnified 100 times). Note the vertical tubes or cells of wood fibers and the bundles of horizontal fibers lying between them.

them and lying radially. These small bundles of cells are termed pith rays. They are formed much as if a knife blade had been thrust radially into the tree crowding between the vertical cells. Figure 26 shows a magnified piece of wood with the vertical cells and pith rays. The cross sections of the pith rays appear on a magnified tangential or flat-grained face of timber as figures tapering on each end, with the long axis vertical, and on a radial section as light-colored bands. In oak, for example, the pith rays are very much in evidence, and form the figures in quartered material. In the conifers, however, the pith rays are not generally noticeable. Not infrequently the cells of which a tree is built up follow a spiral course around the pith instead of lying vertically. Figure 27 shows a tree of this kind. In such trees the cross sections of the pith rays are also inclined or lie diagonally instead of vertically and form an indication of spiral grain. It is quite possible for a piece to be straight-grained, so far as the annual rings are concerned, and still to have a spiral grain. Spiral grain is often indicated in seasoned material by the diagonal direction of fine surface checks which occur at the pith rays. In Fig. 28 are shown three views of a piece of spruce with spiral grain. The danger of using such material where strength is necessary is evident. Failure due to spiral grain in a bridge stringer is shown in Fig. 29. Splitting a block of wood radially will show whether or not it has spiral grain.

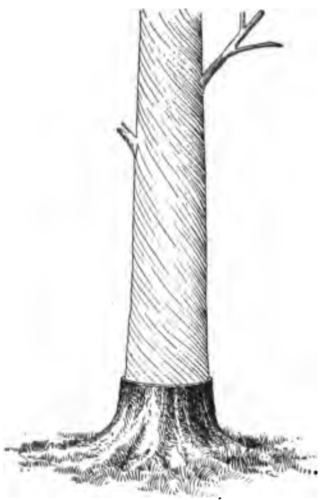


Fig. 27.—Tree with spiral grain.

Diagonal grain or spiral grain with an inclination of more than 1 in 20 to the edge of a beam is apt to cause failure and should not be allowed in high-grade material.

Moisture.—The effect of moisture on strength is very marked in small clear pieces of wood. In Fig. 23 the strength of the green material averages about three-quarters that of the air-dry material, and small kiln dry pieces are frequently over twice as strong as similar green ones. In large pieces, however, the effect of moisture is much less. Under present methods of seasoning structural material, any increase in the strength of the wood fiber is frequently offset by the weakening effect of checks and shakes induced in the process, so that the strength of large seasoned beams is, on the average, increased little over that of green beams. In Table 8, values for green and air-seasoned material for a number of species are compared. The green material in each case is taken as having a value of 1.00 and the corresponding value for the air-seasoned material is given. The tests were made by dividing the shipments of each species into two parts, one of which was tested green and the other after

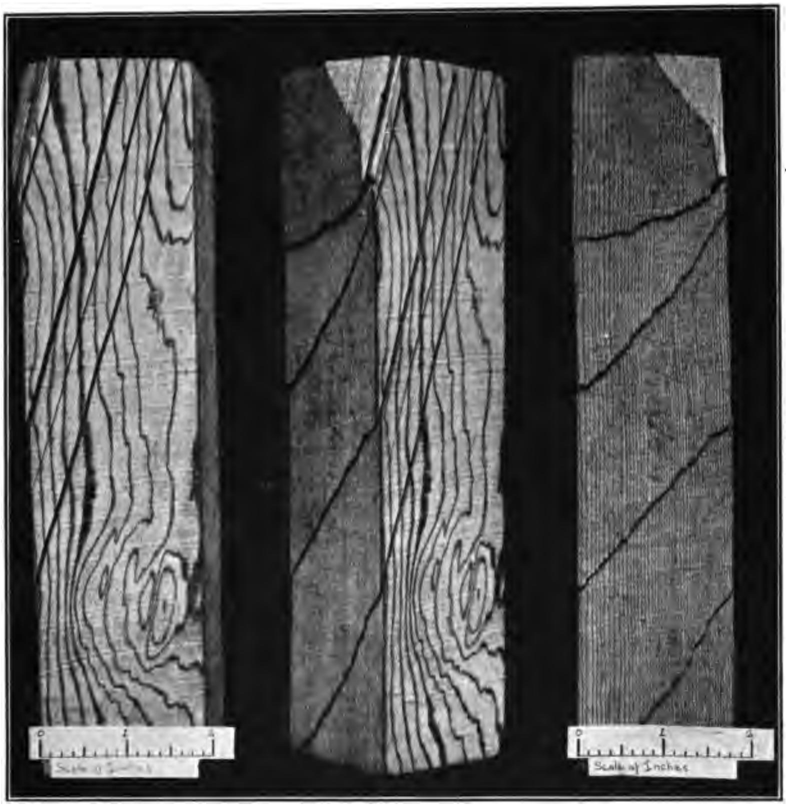


FIG. 28.—Spiral grain in Sitka spruce.

FIG. 29.—Failure due to spiral grain. Views of side and bottom of central portion of 8″ × 16″ × 16′ stringer after test. It will be noted that the lines of failure do not follow the visible grain (lines formed by cutting the annual rings).

TABLE 8.—RATIOS OF AVERAGE STRENGTH VALUES FOR AIR-SEASONED MATERIAL TO THOSE FOR GREEN MATERIAL
(Values for green material = 1.00)

Species	Bending				Compression parallel to grain			Compression perpendicular to grain	Shear
	Fiber stress at elastic limit, pounds per square inch	Modulus of rupture, pounds per square inch	Modulus of elasticity, 1,000 pounds per square inch	Horizontal shear, pounds per square inch	Crushing strength at elastic limit, pounds per square inch	Crushing strength at maximum load, pounds per square inch	Modulus of elasticity, 1,000 pounds per square inch	Fiber stress at elastic limit, pounds per square inch	Shearing strength, pounds per square inch
Longleaf pine:									
Structural sizes	0.99	0.94	1.16	0.77	1.00	1.00	....	1.01	....
Small specimens	1.36	1.27	1.13	....	....	....	....	....	1.01
Douglas fir:									
Structural sizes	1.15	1.06	1.02	1.33	1.18	1.22	0.73	1.12	....
Small specimens	1.28	1.25	1.06	....	1.10	1.24	0.56	....	1.08
Shortleaf pine:									
Structural sizes	1.44	1.19	1.17	1.10	1.66	1.76	1.26	2.26	....
Small specimens	1.79	1.57	1.28	....	....	1.79	....	2.32	1.61
Western larch:									
Structural sizes	1.05	1.18	1.14	1.18	....	1.64	....	1.31	....
Small specimens	1.38	1.42	1.19	....	....	1.60	....	....	1.29
Loblolly pine:									
Structural sizes	1.16	1.19	1.07	1.30	1.47	1.46	2.20	1.31	....
Small specimens	1.26	1.19	1.02	....	....	1.71	....	....	1.77
Tamarack:									
Structural sizes	1.33	1.21	1.10	1.15	1.40	1.34	0.98	....	....
Small specimens	2.33	2.26	1.69	....	....	1.60	....	....	1.32
Western hemlock:									
Structural sizes	1.25	1.21	1.20	1.07	1.67	1.73	1.32	1.09	....
Small specimens	1.44	1.42	1.17	....	1.55	1.59	1.11	....	1.47
Redwood:									
Structural sizes	0.92	0.87	0.85	....	....	1.16	....	1.21	....
Small specimens	1.00	1.12	1.08	....	....	1.29	....	0.99	0.90
Norway pine:									
Structural sizes	1.63	1.57	1.25	1.20	1.48	1.66	1.36	....	....
Small specimens	1.88	1.64	1.21	....	....	3.01	....	....	1.94

thorough air seasoning. While the results show that, in general, all of the mechanical properties are increased by seasoning, this increase is irregular in the structural sizes. In the small sizes an increase in strength would of course be expected. It has been found that if the moisture content of a seasoned timber is increased it loses strength and that if it is thoroughly soaked with

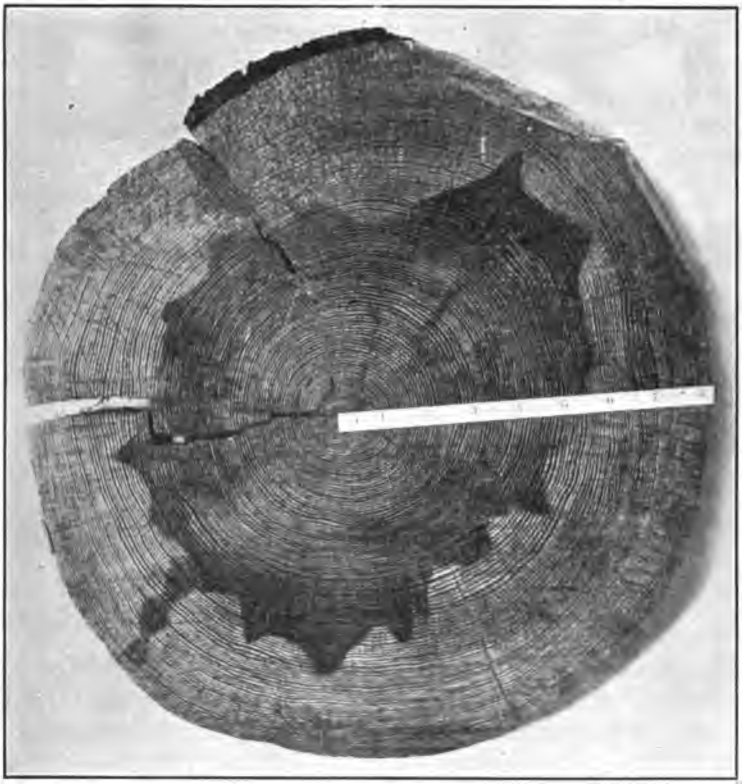


Fig. 30.—Cross section of longleaf-pine tree showing sapwood and heartwood.

water it will be weaker than when green. It is hardly safe in designing timber structures to depend upon an increase in strength in timbers due to seasoning.

Sapwood.—The sapwood forms the layer between the bark and the heartwood. Sapwood is generally considerably lighter in color than the heartwood in the species commonly used for structural purposes. Figure 30 shows the heartwood and sapwood in a cross section of longleaf pine. As a tree grows, the sapwood is continually changing into heartwood and new sapwood is constantly being added at the circumference. All of the heartwood in a mature tree was at one time sapwood. The proportion of sapwood as such has no bearing on the strength of a stick of timber. If a tree is cut at a time when it is forming its densest wood so that this dense wood is still sapwood, pieces cut from the sapwood will be the stronger. If, on the other hand, it is cut later in life when the wood being formed as sapwood is not so dense and the denser wood has changed to heartwood, then pieces cut from the heartwood will be the stronger. In mature coniferous trees the sapwood is generally weaker than the heartwood.

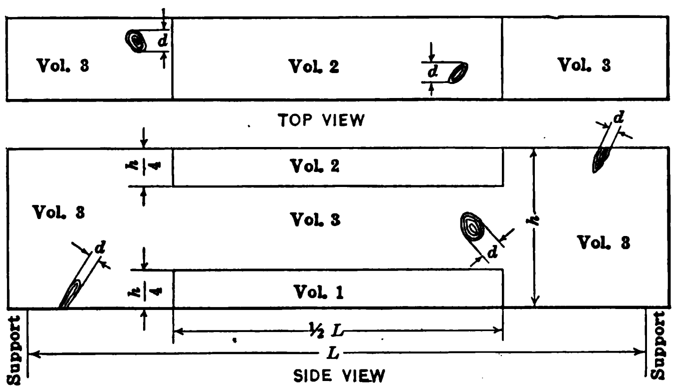


FIG. 31.—Division of beam into volumes for location of knots. Measurement of knots on horizontal and vertical face of beam. d = diameter of knot.

Defects.—Knots, checks, and shakes are the most common defects affecting strength. In timber for use as beams, the influence of knots on strength is largely a matter of location. Figure 31 shows a method of dividing a beam into three volumes with reference to the location of knots. Numerous tests have shown that knots occurring in Volume 1, which occupies the lower quarter of the central half of the beam, have considerably more weakening effect than similar knots occurring in other volumes. Loose or rotten knots are of course more harmful than those closely knit with the surrounding wood. A comparatively small knot situated near enough to the lower edge of a beam to turn the grain off is more harmful than a larger knot so placed as to allow the grain to be continuous in passing. In some cases knots near the neutral plane (the horizontal plane passing through the center of a beam) may act as pins and tend to strengthen the beam against failure in horizontal shear or splitting from end to end along the center. Figure 32 is a view of a beam that has failed in horizontal shear. In a series of tests[1] on loblolly pine beams those with knots in Volume 1 had about 75 per cent. of the strength of sticks with knots in the remaining portions. Tests on short columns[2] of Douglas fir, western hemlock, and

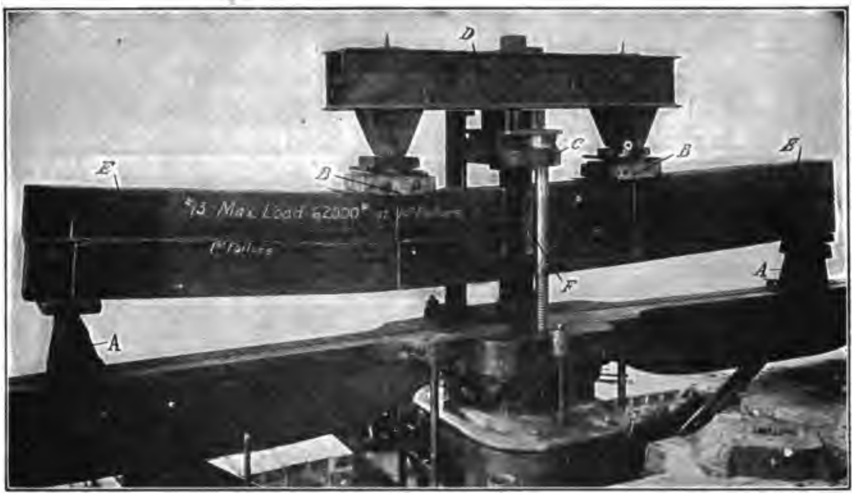


FIG. 32.—View of beam at completion of test showing failure in horizontal shear. Note that beam has split along center so that top half projects above lower half at end. *AA*, support for beam on weighing platform. *BB*, points where load is applied. *C*, head of screw press. *D*, straining beam. *EE*, fine wire stretched along center of beam. *F*, scale used with wire for measuring deflection of beam under load.

western larch indicate that the crushing strength of material with knots is less than that of clear material. The decrease in strength was approximately 5 per cent. in columns with knots ½ inch or less in diameter, from 10 to 15 per cent. in columns with knots between ½ inch and 1½ inches in diameter, and from 15 to 20 per cent. in columns with knots over 1½ inches in diameter.

Checks are caused by the stresses set up in seasoning. Structural timber in large sizes is difficult to season without more or

[1] See Forest Service *Circular* 164, "Properties and Uses of Southern Pines."

[2] See Forest Service *Bulletin* 108, "Tests of Structural Timbers."

less checking, even under favorable conditions; frequently it is so exposed as to cause the surface to dry much more rapidly than moisture can be transmitted from the inner portions to the surface. The outer portions dry and shrink while the center is still wet, and checking results.

A shake is a separation between two annual rings. Generally the separation occurs in only part of the ring, but sometimes it is complete. Shakes are ascribed to the bending action of wind on the standing tree. They are frequently not visible in green timber, but show up later during seasoning.

Both checks and shakes weaken beams in their ability to resist horizontal shear in proportion as they affect the area of the beam near the neutral axis. When a load is placed on a beam supported at the ends, the beam has a tendency to shear or split lengthwise along the center of the vertical side and form two beams, each one-half the size of the original beam. If the beam is already partially separated along the center by checks and shakes, it is obvious that it will be more easily split along this plane than if the area is intact.

In the case of a stringer, 8 × 16 inches in section, tested in bending over a 15-foot span, failure may occur by tension or tearing apart of the fibers in the lower part of the beam, by compression or crushing in the upper part, or by shearing along the neutral axis. The results of shearing tests on small, clear pieces show that, under the conditions given, failure would always occur in tension or compression long before the beam could reach its maximum shearing stress, provided the shear-resisting area was intact. In tests on commercial material, however, horizontal shear is a common form of failure, which is due to the fact that the area that resists shear is frequently weakened by checks and shakes. A comparison of the stresses obtained from tests on 8-inch by 16-inch by 16-foot stringers and from those in small clear pieces shows that the shear-resisting area in commercial material is frequently reduced about 50 per cent. by checks and shakes. Table 9 shows the calculated shearing stresses developed in structural beams of a number of species.

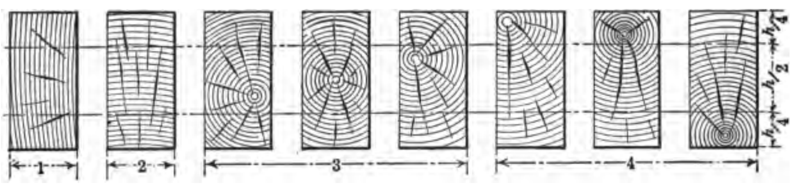
Table 9 separates the timbers tested into three groups: (1) Those which failed first in horizontal shear, (2) those which had secondary failures in horizontal shear, and (3) those which did not fail in horizontal shear. The number of specimens falling into each group is given as a percentage of the total number

TABLE 9.—CALCULATED SHEARING STRESSES DEVELOPED IN STRUCTURAL BEAMS

Species.	Total number of tests		First failure by shear				Shear following other failure				No shear failure			
			Green		Dry		Green		Dry		Green		Dry	
	Green	Dry	Per cent. of total	Average calculated shear, pounds per square inch	Per cent. of total	Average calculated shear, pounds per square inch	Per cent. of total	Average calculated shear, pounds per square inch	Per cent. of total	Average calculated shear, pounds per square inch	Per cent. of total	Average calculated shear, pounds per square inch	Per cent. of total	Average calculated shear, pounds per square inch
Longleaf pine	17	9	54	353	56	272	23	374	0	...	23	218	44	286
Douglas fir	191	91	2	166	6	221	22	295	49	294	76	264	45	247
Shortleaf pine	48	13	17	332	46	364	6	327	8	418	77	276	46	340
Western larch	62	52	8	288	27	340	16	314	21	370	76	268	52	287
Loblolly pine	111	25	7	335	28	434	2	356	16	546	91	237	56	255
Tamarack	30	9	10	261	33	299	3	263	0	...	87	228	67	283
Western hemlock	39	44	5	288	23	307	28	281	68	438	67	250	9	417
Redwood	28	12	7	302	0	...	11	218	17	250	82	283	83	227
Norway pine	49	10	6	232	10	278	6	266	0	...	88	209	90	304

of specimens tested. It will be noticed that of the seasoned timbers from 6 to 56 per cent. failed first in shear, and that in Douglas fir, loblolly pine, and western hemlock a considerable proportion had secondary failures in horizontal shear. These figures indicate strongly the need of taking horizontal shear into consideration in the design of timbers tructures. They also show the necessity of using stresses much lower than those indicated by tests on small clear specimens. In short, deep beams special attention should be given to horizontal shear.

Position of Pith in Cross Section.—Timbers containing the pith or center of the tree are frequently spoken of as "boxheart." When the timber was tested in bending, failure occurred more



1 - Pith not in Cross-Section Rings Vertical
2 - " " " " " Rings Horizontal
3 - Pith within Center Half of Cross-Section
4 - " " Upper or Lower Quarters of Cross-Section

FIG. 33.—Various positions of pith in cross section.

frequently by longitudinal shear when the pith was in the center half of the cross section than when it was in the upper or the lower quarter. Vertical grained structural material was also more apt to fail by longitudinal shear than material with the grain horizontal. In material with the pith near the center of the cross section or with the grain vertical, radial checks are apparently able to exert their greatest influence in weakening the area that resists longitudinal shear. Figure 33 shows the various kinds of cross section that may occur with reference to the pith.

CHARACTERISTICS AFFECTING DECAY IN TIMBER

Conditions in the Wood Itself.—The characteristics to which special attention is given in judging the durability of any one wood are the proportion of sapwood, the moisture condition, the amount of resin, and the general condition of the piece with reference to sap stain, which may indicate incipient decay, and with reference to defects which often form the starting places for decay. Marked variation from the characteristic color often indicates incipient decay, especially when it gives a streaked or spotted effect. Some of the blue stains noticeable in sapwood are not injurious to the timber; but if abnormal color is associated with punkiness or softness noticeable by pricking the wood with a knife blade, it is highly probable that there is decay. Past records of the durability of various woods under the same conditions will give the best criterion of their relative decay-resisting ability for a certain use. Little is known of the reason why certain woods are more durable than others. In the case of mechanical properties, such as strength, stiffness, and hardness, practically all of them are dependent on the density or dry weight of the wood; and it is quite safe to calculate that the heavier the wood the higher will be the values for its mechanical properties. The durability of various woods, however, has apparently nothing to do with their density. The heavier species are not necessarily the most durable; some of the lighter woods, such as cedar and redwood, have excellent lasting properties, while some of the heavier hardwoods, such as hickory and red oak, are notably less decay resisting; and, on the other hand, the lighter woods, basswood and cottonwood, are not durable, while the heavier woods, osage orange and locust, are durable. Table 10 gives the estimated life of a number of untreated woods in several forms.

In practically all woods the sapwood is less resistant to decay than heartwood; therefore in timber that is to be used without preservative treatment, the proportion of sapwood has an important bearing on the value of the material. In the smaller sizes of structural timber, 2 × 10, 6 × 8, etc., frequently no sap at all is allowed. In the larger sizes, 10 × 12 and 8 × 16, two inches of sap is often allowed on several edges, or its equivalent on one edge. Where the timber is to be given an antiseptic treatment, sapwood is not generally considered detrimental; for it takes treatment more easily than heartwood, and when properly treated should be equally as decay-resistant as the treated heartwood.

The moisture condition of structural timbers has had but little attention until the last few years. The amount of moisture in timber to be used in interior construction, especially in poorly ventilated places, is of considerable importance from the stand-

TABLE 10.—LIFE OF UNTREATED WOOD

The estimates given are based on Forest Service experiments and general information. The durability of wood will vary from the estimated averages with local conditions.

Species	Ties properly tie plated	Poles	Posts	Lumber placed under conditions subjecting it to decay
	years	years	years	years
Black locust	20 or over	......	Over 15	....
Redwood	10 to 12	12 to 15	12 to 15	12 to 15
Osage orange	....	......	Over 15	....
Cypress (heart)	10 to 12	12 to 15	12 to 15	12 to 15
Mulberry	....	......	Over 15	....
Yew	....	......	Over 15	....
Eastern red cedar	....	......	12 to 15	....
Western juniper	....	......	Over 15	....
Northern white cedar	10 to 12	12 to 15	12 to 15	12 to 15
Southern white cedar	....	6 to 8	6 to 8	12 to 15
Western red cedar	....	9 to 11	9 to 11	12 to 15
Port Orford cedar	10 to 12	......	......	....
White oak	6 to 8	6 to 8	6 to 8	6 to 8
Catalpa	....	......	12 to 15	....
Chestnut	6 to 8	12 to 15	9 to 11	12 to 15
Longleaf pine	6 to 8	6 to 8	6 to 8	9 to 11
Douglas fir	6 to 8	6 to 8	6 to 8	9 to 11
Red spruce	6 to 8	......	......	6 to 8
White pine	3 to 5	......	......	6 to 8
Western yellow pine	3 to 5	2 to 5	2 to 5	6 to 8
Sugar pine	....	......	......	6 to 8
Engelmann spruce	....	......	6 to 8	....
Elm	....	......	......	6 to 8
Red oak	3 to 5	......	2 to 5	3 to 5
Lodgepole pine	3 to 5	2 to 5	2 to 5	......
Aspen	....	......	2 to 5	....
Ash	....	......	2 to 5	3 to 5
Hemlock	3 to 5	......	......	6 to 8
Tamarack	3 to 5	......	2 to 5	6 to 8
Sitka spruce	....	......	2 to 5	....
Birch	3 to 5	......	......	3 to 5
Maple	3 to 5	......	......	3 to 5
Alpine fir	....	......	2 to 5	....
Loblolly pine	3 to 5	2 to 5	2 to 5	....
Red gum	3 to 5	......	2 to 5	3 to 5
Western larch	3 to 5	......	......	....
Poplar	....	......	......	3 to 5
Cottonwood	....	......	......	3 to 5
Tupelo	....	......	......	3 to 5
Basswood	....	......	......	3 to 5
Beech	3 to 5	......	......	3 to 5
Sycamore	....	......	......	3 to 5

point of durability. Many instances are on record where structural timber of high quality has been used in mill construction without proper drying and has become infected with so-called "dry rot" within a year or two after its placement, while timber of the same quality, but properly seasoned, has given satisfaction under similar conditions for ten or fifteen years. Timber put in position green is also liable to shrinkage or distortion, which under certain conditions may be very objectionable.

It is not always easy to judge the condition of seasoning of structural timber from a visual inspection. The number and character of checks will give some idea as to the seasoned condition, and the amount of weathering on the sides and ends is also a rough indicator of the moisture condition. If it is possible to weigh the pieces, their weights may be compared to calculated weights of the same sized sticks of dry material (see Table 3, Chapter II); and if they are very wet, the actual weights will show a considerable excess over the calculated weights for air dry timber. A more definite method is to calculate the moisture from borings made in representative places on the sides of the stick. An inch bit is satisfactory. The depth of the hole varies with the size of the stick, half or a third of the way to the center being considered deep enough. The borings are collected and weighed immediately and then dried to constant weight at approximately 212° F. (100° C.) and weighed again. The difference between the two weights, divided by the dry weight, and multiplied by 100 gives the moisture content of the stick in per cent. of the dry weight. If more than one boring is made, the results are averaged.

Defects, such as checks and knots or knot holes, should be carefully inspected, as they form excellent places for the lodgement of the spores of fungi; and if any incipient decay is indicated, the piece should either be thrown out or steps taken to check the decay before putting the timber in use.

Inspections of a number of buildings which have given trouble on account of decay have shown that any one of the following causes may result in rapid deterioration of a building:

1. The use of green timber.
2. Allowing timber to get wet during construction.
3. Leaks or lack of ventilation, allowing the timber to absorb moisture after the building is finished.
4. The use of timbers containing too much sapwood.

5. The use of timbers which have already started to decay.

The avoidance of these conditions will, as a rule, prevent decay. In special cases, however, decay can only be prevented by preservative treatment. Wood that has been in contact with damp ground usually contains the right amount of moisture for

Fig. 34.—Decay in braces at a joint where moisture has collected.

decay. Also, where timber is in contact with wood or other material water frequently collects in the joints and keeps the wood moist and in a condition favorable to decay. Figure 34 shows a condition of this kind.

The presence of resin in wood keeps out moisture and air, and in this way it acts as a preservative although it is not highly poisonous to wood-destroying fungi. It is quite a common occurrence to find lying in the woods pine logs which at first sight are apparently in a fair state of preservation, but of which the sap is found on examination to be entirely decayed, the only portions remaining sound being such parts of the heart as are permeated with resin. It is also a well-known fact that fence posts chosen from pitchy material last longer than similar posts from wood with a small pitch content. While a high per cent. of resin undoubtedly adds markedly to durability, the effect of the amount of rosin generally found in structural timber is not definitely known.[1]

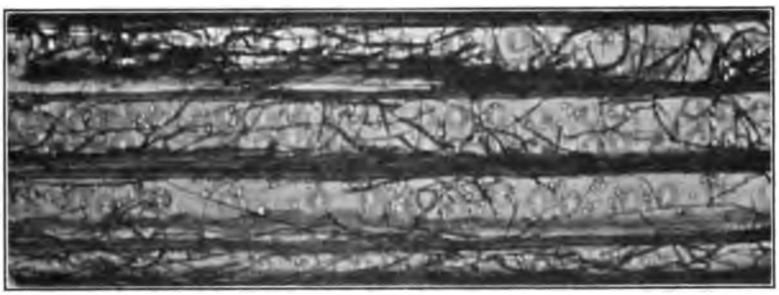


FIG. 35.—Thin section of rotting pine showing fungous threads and holes where these have penetrated through the walls of the wood cells.

Agencies that Destroy Wood.—The principal agencies that destroy wood are fungi, insects, and borers.

Decay in timber is generally due to the walls of the cells, of which wood is built up, being eaten by certain fungi. The life of a wood-rotting fungus has two stages: (1) the mouldlike vegetative stage, during which the cottony threads or mycelium penetrate through the wood (Fig. 35); and (2) the fruiting stage, during which the shelflike or "toadstool" outgrowths, or in some cases, merely surface incrustations, are formed (Figs. 36, 37, and 38). The fruit bodies produce spores, and these blow about like seeds and, if they lodge where growth conditions are right, germinate to produce the cottony threads which rot the timber. The fungus may also spread directly by the mycelium's

[1] Mr. F. J. Hoxie of the Associated Factory Mutual Fire Insurance Companies of Boston discusses the question in detail in his book, "Dry Rot in Factory Timbers."

passing from diseased to adjacent sound timbers, as shown in Fig. 39.

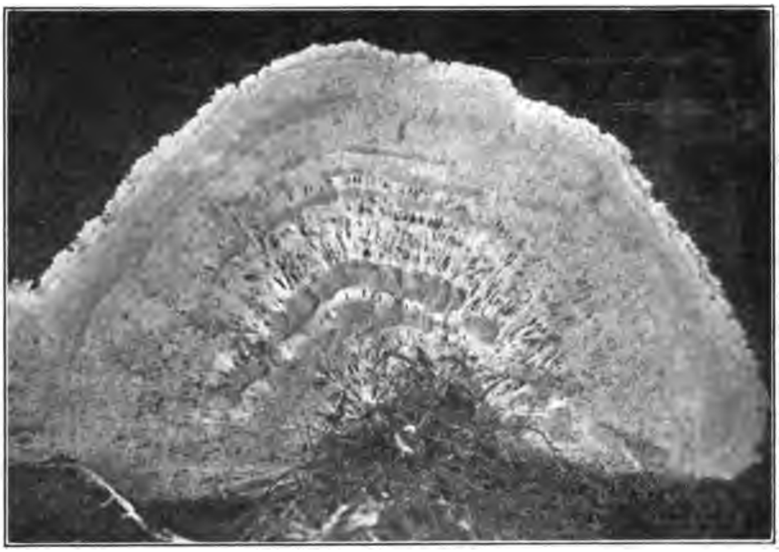


FIG. 36.—Fruiting body of wood-rotting fungus on a board from a clay mine.

The growth of fungus is dependent on food, moisture, temperature, and at least a small amount of air. A large part of wood

FIG. 37.—Mushroom on a rotten log.

FIG. 38.—A surface fungous growth.

substance is suitable for fungus food. In badly decayed pieces about 70 per cent. of the original weight has been lost. A considerable amount of moisture is necessary for rapid decay. Air dry timber containing about 20 per cent. moisture will not rot in dry weather; but during continuous rainy, damp weather enough moisture may be absorbed from the air to start decay. Wet logs buried deeply will stay sound because sufficient air to support fungous growth can not get to them. Different temperatures exert a marked influence on decay. Each wood-rotting fungus has an optimum for rapid growth. Most thrive around 80° F. Comparatively small rises above the optimum are often fatal. It is good practice to heat wooden factory buildings thoroughly soon after completion in order to kill surface growth of fungi. Low temperatures are not harmful to them; practically all fungi survive the severest winters. The fruit bodies or spores of

A *B*

FIG. 39.—Spread of fungus by contact. *A*, open shed where infection has spread upward from decayed piece on ground. *B*, corner of building where infection has spread from decayed sill.

fungi are known to have remained alive for as long as eight years when in a dry condition.

Insects damage timber by excavating burrows or galleries in the wood. Round timber, rough or dressed lumber, and finished wood products are all subject to attack. Construction timber, and other wood materials used in buildings, bridges, railroad construction, mining, etc., are often infested by wood-boring grubs, powder post borers, white ants, and other insects. It is often difficult to estimate the extent of the injury to timber from insects by the evidences of their work on the surface. Pieces of timber showing signs of containing active borers should of course not be used in building, as the insects may weaken the pieces and spread to others. Borers may enter the log through a single small hole and then excavate a great many winding burrows whose extent can not be estimated from a surface inspection. Timber borers may be either beetles or worms. The powder post beetle, whose work is illustrated in Fig. 40, is one of the common wood borers. These beetles attack the sapwood of

Fig. 40.—View of surface and interior of axe handle attacked by powder post borers. Note that few holes on surface do not indicate extent of damage to interior.

partly or thoroughly seasoned hardwoods, especially ash, hickory, and oak. They do not attack the heartwood.[1] White ants[2] or termites, black ants, and carpenter bees are other wood-boring

[1] See Farmers' Bulletin 778, U. S. Department of Agriculture, "Powder-Post Damage by Lyctus Beetles to Seasoned Hardwood," by A. D. Hopkins and T. E. Snyder, Bureau of Entomology.

[2] See Farmers' Bulletin 759, U. S. Department of Agriculture, "White Ants as Pests in the United States and Methods of Preventing their Damage," by T. E. Snyder, Bureau of Entomology.

insects. Termites sometimes cause an almost complete destruction of the timber attacked by leaving nothing but an outer shell. They operate principally in the more southern States.

Marine borers which operate in the water on piling, dock timbers, the hulls of wooden vessels, etc., are of two general

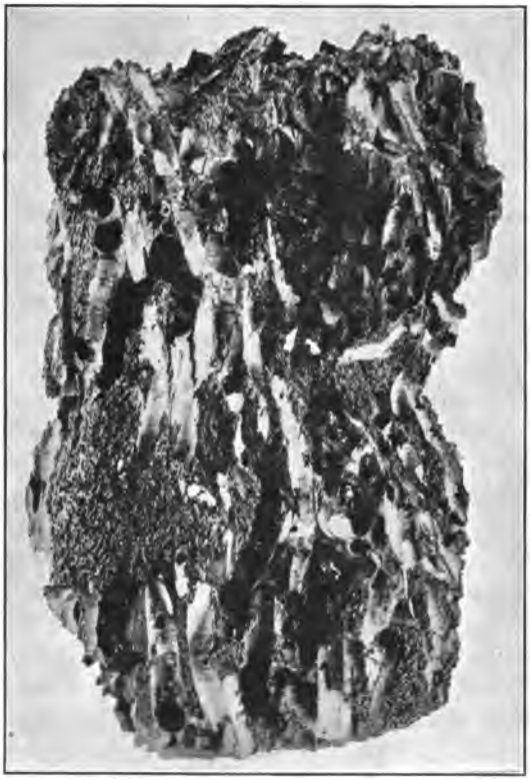


Fig. 41.—Portion of spruce pile destroyed in three years by marine borers in the harbor of Klawock, Alaska.

forms commonly known as "shipworms"[1] and "wood lice."[2] Shipworms bore into wood exposed to their attack under the water when they are very young. The hole by which the worm enters the wood is minute but the cavity is enlarged rapidly inside the

[1] The name includes the mollusks, zylotrya, and teredo.
[2] The name includes the crustaceans, limnoria, chelura, and sphæroma.

timber to accommodate the growing body. In rare cases a length of 6 feet with a diameter of 1 inch is said to be attained. Of the crustacean borers, limnoria is the most common. It is about the size of a grain of rice and bores countless galleries in the wood close together, which so weaken the surface of the timber attacked that it is washed off by wave action and new wood exposed to attack. Figure 41 shows a portion of a pile destroyed by both classes of borers.

Alkaline soils, birds, and sap stain are other agencies of less importance than fungi, insects, and marine borers but which cause deterioration in timber.

Relations Indicated by Tests of Structural Timbers

1. All the species tested seem to be subject to the same general laws regarding the relation of mechanical to physical properties.

2. The proportion of summerwood in structural timber is a means of judging its density and strength.

3. Seasoning can not be counted on to strengthen structural timbers.

4. Seasoning increases the liability to failure by horizontal shear.

5. The strength of beams is seriously lowered by knots or irregular grain in the center half near the lower edge.

6. Timbers that have been seasoned and soaked are not as strong as they were before seasoning.

7. The presence of knots generally indicates wood of low density and strength, such as is common in top logs.

8. Diagonal grain or spiral grain is a serious defect in structural timber.

9. Certain rates of growth in some species are generally associated with strong material, but rate of growth should not be depended on to indicate satisfactory timber.

10. The use of green timber, timber with considerable sapwood, and timber with incipient decay is frequently the cause of deterioration in buildings.

11. Structural timbers that show signs of containing active wood borers should not be used in permanent building operations.

The Grading of Structural Timbers

The purpose of grading rules for structural timbers is to make possible the separation of such material by inspection into groups or grades, so that each stick in a certain grade will be of approximately the same value for certain purposes.[1]

Until recent years, large quantities of high-grade timber suitable for engineering construction were available in the United States, so that little necessity was felt for economy in sizes or careful quality grading. Engineers and builders demanded and received structural timber of the highest quality. There was an ample supply in the forests to cut from, and timber of questionable quality was left. Years of heavy cutting in the finest stands of structural timber, naturally, have had their effect, and in many localities it is now somewhat difficult to obtain shipments of the highest quality material. The practice of cutting timber of an intermediate or poor quality, as well as high-class timber, into structural material and the growing tendency to place these timbers of various qualities on the market has made the question of grading rules and methods of inspection of increasing importance.

Lumber manufacturers' associations have done much to standardize the grading rules for different species and classes of timber. Many grading rules, however, are based entirely on the number and character of defects in the pieces; and while this basis of classification has proved fairly satisfactory in grading sawmill products, such as lumber and boards for the woodworking industries, it has not been very effective in separating structural timbers according to strength.

The American Society for Testing Materials was the first technical association to formulate a specification for structural timber in which the position of defects was considered. This specification was based on tests of structural timbers made by the Forest Service and other agencies. The introduction of such a specification was a distinct step forward, as it has been abundantly proved in tests that a beam with large knots close to the edges and near the center of the span is not as strong as a similar beam with the same number and kind of knots differently located.

[1] A timber specification is a set of requirements prepared with the intention of having any piece of timber that fulfils the requirements suitable for a given purpose. Grading rules are generally prepared by the timber producer and specifications by the timber user.

The strength, or mechanical properties, of timber is dependent upon the quality of the wood, irrespective of defects as well as upon the location, number, and condition of defects. This quality is indicated by the dry weight of the wood, *i.e.*, the heavier the wood or the greater its specific gravity, the greater is its strength, stiffness, toughness, etc. The relative dry weight of different pieces of wood may be judged by comparing the proportion of summerwood in their cross sections. By summerwood is meant the darker harder portion of the annual rings. The incorporation in grading rules of some requirement covering the quality of the wood has been advocated by the Forest Service for a number of years, and recently the American Society for Testing Materials and the Southern Pine Association have adopted rules which provide for the quality of the wood itself, as well as limit the position, size, and condition of defects. The first definite commercial application of inspection by the proportion of summerwood in the annual rings was the employment of the so-called "density rule" by the Panama Canal in the inspection of a large shipment of southern yellow pine over which a controversy had arisen.

Engineers and architects have for some time been unnecessarily confused by the large number of different grading rules for structural timbers that are in use in the United States. Practically all of the lumber associations have adopted rules for the purpose of classifying the lumber manufactured by their members. The railroads also have specifications under which their timber is bought, and a number of the engineering societies have from time to time brought out timber specifications or grading rules. Often when it is desired to consider the use of a new species for structural purposes, it is impossible with the present confusion in grading rules for the purchaser to select a different species with any definite assurance that the grade of material he selects corresponds in strength with the grade of material he has been using. Many of the present rules are either very general and loose, leaving everything to the opinion of the inspector, or else so rigidly drawn as to exclude much timber of high strength.

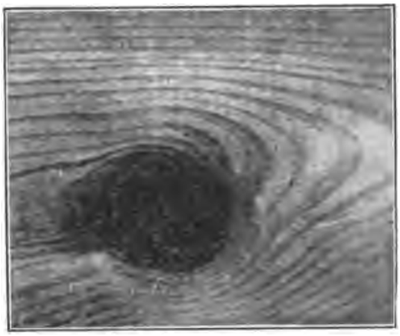
The most efficient grading rules are those which will exclude material not suitable for the purpose intended and at the same time will not exclude more than a reasonable amount of material belonging in the grade. The most important point is that no pieces which it would be dangerous to use are passed by the rule, and that in keeping out the dangerous material the smallest possible amount of material is excluded that really belongs in the grade from the standpoint of strength. Grading rules should be based on test data and a knowledge of the requirements of the trade and the ability of the producer to meet these requirements. Under present conditions in the lumber industry, practical grading rules for structural timber must be simple and such that the timber can be inspected in a reasonable time, in addition, of course, to dividing the timbers satisfactorily into groups containing pieces of approximately the same strength.

The two properties essential in structural timber are strength and durability, and the degree to which it possesses these properties, *i.e.*, the more load it will carry and the longer it will last, the greater will be its value. The quality of the wood as indicated by the character of the annual rings in the cross section and the location and size of defects makes it possible to classify timber from the strength standpoint. Durability is judged largely from the proportion of sapwood, which decays much more quickly than heartwood. Little is known of the effect of density in any one species; *i.e.*, whether a heavy piece of Douglas fir is more durable than one of lighter weight has yet to be proved. A high per cent. of resin is favorable to durability. The moisture condition of structural material from a durability standpoint is an important consideration. Seasoning is especially necessary for inside work.

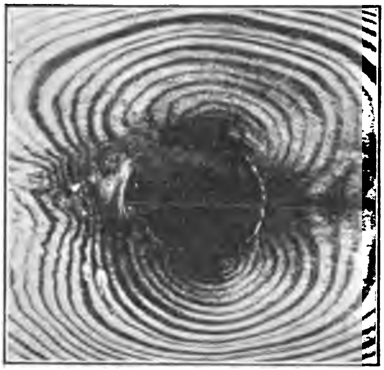
Classification of Defects.—In grading timber the question of classifying knots and limiting such defects as wane, ring shakes, etc., frequently arises. The following definitions and illustrations (Figs. 42, 43, and 44) give what is considered good practice in defining and classifying various characteristics of wood. The definitions are practically the same as those adopted by the American Society for Testing Materials and are very similar to those adopted by the Southern Pine Association and the West Coast Lumbermen's Association.

Classification of Defects in Structural Timber

Knots.—Knots are caused by growing branches or by dead branches adhering to the trunk during the process of growth of the tree. They are classified as follows:

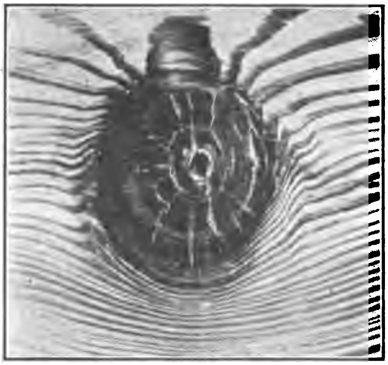


Sound knot

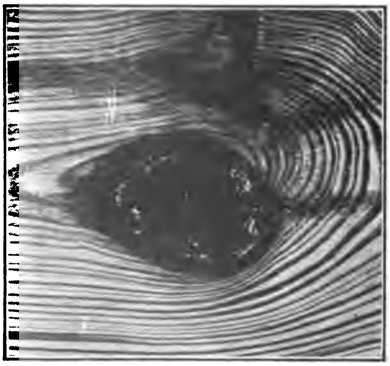


Loose knot

Encased knot



Pith knot



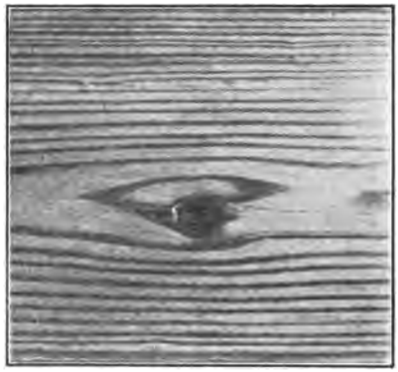
Rotten knot

Fig. 42.—Classification of knots according to quality.

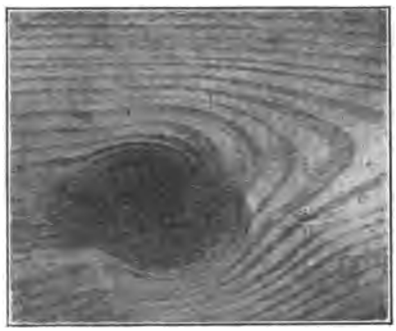
Round knot

Spike knot

A



Pin knot (not over ½″ in diameter)



Standard knot (not over 1½″ in diameter)

Large knot (over 1½″ in diameter)

B

Fig. 43.—Classification of knots according to form (*A*) and size (*B*).

Size		Form		Quality	
Size	Pin	Form	Round	Quality	Sound
	Standard		Spike		Loose
	Large				Encased
					Rotten
					Pith

A *pin* knot is a sound knot not over ½ inch in average diameter.

A *standard* knot is a sound knot over ½ inch but not over 1½ inches in average diameter.

FIG. 44.—Cross section of timber showing several kinds of defects.

A *large* knot is a sound knot more than 1½ inches in average diameter.

A *round* knot is one which is oval or circular in form.

A *spike* knot is one sawn in a lengthwise direction.

A *sound* knot is one solid across its face and as hard as the wood it is in. It is so fixed in the piece as to retain its position.

A *loose* knot is one not firmly held in place.

An *encased* knot is one surrounded wholly or in part by bark or pitch and not intergrown with the adjacent wood.

A rotten knot is one not as hard as the surrounding wood.

A *pith* knot is a sound knot with a pith hole not over ¼ inch in diameter in the center.

Pitch Pockets.—Pitch pockets are openings between the annual rings containing more or less pitch or bark. They are classified as follows:

Size { Small, Standard, Large

A *small* pitch pocket is one not over ⅛ inch wide.

A *standard* pitch pocket is one not over ⅜ inch wide, or 3 inches in length.

A *large* pitch pocket is one over ⅜ inch wide or 3 inches in length.

Pitch Streak.—A pitch streak is a well-defined accumulation of pitch at one place in a piece of timber.

Wane.—Wane is irregularity on the edge of a piece of lumber due to the presence of bark, or breakage, or the absence of wood.

Ring Shakes.—A ring shake is a curved slit or opening between the annual rings in a piece of timber. A through shake is a ring shake which extends from one face to an adjoining or opposite face.

Checks.—A check in a piece of timber is a split or opening, generally at right angles to the annual rings on a cross section and often caused by rapid seasoning. A through check extends from one face to another of a piece.

Rot.—Rot is any form of decay. It may be evident as a dark red discoloration not found in the sound wood or as white or red soft spots.

Cross Grain.—Cross grain occurs in a piece of timber when the fibers of the wood are not parallel to the edges. It may be of two kinds:

Diagonal grain is present when the piece is not sawed parallel to the annual rings and, consequently, the lines formed by cutting the annual rings run diagonally across the stick.

Spiral grain is caused by the fibers of the wood growing spirally around the pith of the tree instead of vertically parallel to the pith.

Various Grading Rules.—The following are examples of specifications and grading rules for structural timber adopted by railroads, lumber associations, etc.

Chesapeake and Ohio Railway Company

Specifications for Longleaf Yellow Pine

All lumber must be cut from living timber of good quality, and must be free from splits, shakes, loose or decayed knots, or defects which impair its durability. It shall be well manufactured to the size ordered, and must be of longleaf virgin pine; no shortleaf yellow pine, bull pine, or loblolly pine will be accepted under this specification.

Y. P.[1] 1

Bridge guard rails, platform joists, signal masts, bumper posts, mail crane posts, trestle posts, cattle guards, semaphore posts, sills and braces, water-tank frames, and dock timbers.

All square lumber shall show two-thirds heart on two sides and not less than one-half heart on the other two sides. Other sizes shall show two-thirds heart on faces, and show heart on two-thirds of the length on edges, excepting where the width exceeds the thickness by 3 inches or over; then it shall show heart on the edges for one-half the length.

Y. P. 2

Bridge cross ties, bridge stringers, water-tank joists, scale timbers, and trestle caps.

On all square sizes the sap on each corner shall not exceed one-sixth the width of the face; when the width does not exceed the thickness by 3 inches to show one-half the heart on narrow face the entire length; exceeding 3 inches to show heart on narrow face the entire length; sap on wide faces to be measured as on square sizes.

Y. P. 3

Boards and plank for flooring.

Boards and plank 9 inches and under wide to have at least one heart face and two-thirds heart on opposite side; boards and planks over 9 inches to have not less than two-thirds heart on both sides.

Chicago Great Western

Standard Specifications for Southern Yellow Pine Bridge and Trestle Timbers

(To be applied to single sticks and not to composite members)

Note.—The "Standard Heart Grade" is intended for general use in bridges and trestles, while the "Standard Grade" is intended for falsework, trestles for filling, and for other temporary construction.

1. Except as noted, all timbers shall be sound, sawed to standard size, full length, square cornered and straight; shall be close grained and free from defects such as injurious ring shakes and cross grain, unsound or loose knots, knots in groups, decay, or other defects that will materially impair its strength.

2. Rough timbers sawed to standard size means that they shall not be

[1] Y. P. = yellow pine.

over ¼ inch scant from the actual size specified. For instance a 12 by 12-inch timber shall measure not less than 11¾ by 11¾ inches.

3. Standard dressing means that not more than ¼ inch shall be allowed for dressing each surface. For instance, a 12 by 12-inch timber, after being dressed on four sides, shall measure not less than 11½ by 11½ inches.

Standard Heart Grade, Longleaf Yellow Pine

4. Stringers shall show not less than 85 per cent. heart on the girth anywhere in the length of the piece; provided, however, that if the maximum amount of sap is shown on either narrow face of the stringer, the average depth of sap shall not exceed ½ inch. Knots greater than 1½ inches in diameter will not be permitted at any section within 4 inches of the edge of the piece, but knots shall in no case exceed 4 inches in their largest diameter.

Douglas Fir and Western Hemlock Bridge and Trestle Timbers

(To be applied to single sticks and not to composite members)

Note.—The "Standard Heart Grade" is intended for general use in bridges and trestles, while the "Standard Grade" is intended for falsework, trestles for filling, and for other temporary construction.

Standard Heart Grade

1. Standard Heart Grade shall include yellow and red Douglas fir and western hemlock, white Douglas fir will not be accepted.

2. All timber shall be live, sound, straight, and close grained, cut square cornered, full length, not more than ¼ inch scant in any dimension for rough timber or ½ inch for dressed timber; free from large, loose or unsound knots, knots in groups, or other defects that will materially impair its strength for the purpose for which it is intended. Subject to inspection before loading.

3. Stringers shall show not less than 90 per cent. heart on each side and edge, measured across the surface anywhere in the length of the piece. Shall be out of wind and free from shakes, splits, or pitch pockets over ⅜ inch wide or 5 inches long. Knots greater than 2 inches in diameter will not be permitted within one-fourth of the depth of the stringer from any corner nor upon the edge of any piece; knots shall in no case exceed 3 inches in diameter.

4. Caps, sills, and posts shall show not less than 85 per cent. heart on each of the four sides, measured across the surface anywhere in the length of the piece. Shall be out of wind and free from shakes, splits, or pitch pockets over ½ inch wide or 5 inches long. Knots shall not

exceed one-fourth of the width of the surface of the piece in which they occur and shall in no case exceed 3 inches in diameter.

5. Longitudinal struts or girts, X braces, sash and sway braces shall show one side all heart, the other side and two edges shall show not less than 85 per cent. heart, measured across the surface anywhere in the length of the piece.

Chicago, Burlington and Quincy Railroad Company

Construction Timbers

Must be sawed full size, square edged and be sound and well manufactured. Must be free from black or rotten knots; or from knots, checks, or pitch seams large enough to weaken the piece in any way.

Chicago and Northwestern Railway Company

Specifications for Timber

Must be well manufactured from live timber, no black, large or weakening knots, cut full size, exact. It is understood that shipments on this order are subject to inspection and acceptance at destination.

Pennsylvania Railroad

Longleaf Yellow Pine

Longleaf yellow pine shall be cut from sound, live timber, well manufactured, full size, saw butted and square edged, unless otherwise specified.

Merchantable shall show some heart the entire length on one side for pieces 9 inches and under and on two opposite sides for pieces over 9 inches. On 10 per cent. of the pieces for any one size wane one-eighth the width and one-fourth the length of the piece may be allowed on one corner or its equivalent on two corners.

Yellow Fir

Common car sills and framing shall be cut from sound, live timber, well manufactured, full size, and free from rot, shakes, unsound knots, cross grain, bark or wane edge.

This grade will admit sap, any number of sound knots, provided they are intergrown and not in clusters and do not exceed one-fourth the width of the piece, and pitch pockets or pitch seams which do not weaken the piece for the purpose intended.

GRAND TRUNK RAILWAY SYSTEM

Stringers, caps, guard rail, bridge ties, tank posts.

Longleaf Yellow Pine, 90 Per Cent Heart

ILLINOIS CENTRAL RAILROAD COMPANY

Specifications for Pine and Cypress Bridge Timber

General Specifications for All Kinds of Pine Timber

All timber shall be sawed from sound live trees and shall be cu. square and out of wind, with adjacent faces at right angles to each othert No piece shall vary more than one-quarter of an inch less than the specified dimensions. All timber shall be free from thorough, round or injurious wind shakes, large, loose, grouped or unsound knots, pitch seams, red heart, decay or other defects which may impair the strength or durability of the timber.

Class "A."—Timber in this class shall be two-thirds heart faces except when it is specified that there shall be two-thirds heart on edges. Nothing but longleaf yellow pine accepted.

Class "B."—Timber in this class shall be 85 per cent. heart. Nothing but longleaf yellow pine accepted.

Class "C."—Timber in this class shall be square edged and sound, and unless longleaf yellow pine is specified, shortleaf pine and loblolly are preferred.

Specifications for Timber to be Used in Building Construction

All building material shall conform to classification of the Yellow Pine Manufacturers' Association,[1] adopted at New Orleans, January 24, 1906.

Platform plank shall have one heart face, except that 1-inch sap will be allowed on one corner of this face—no sap restrictions on opposite face.

Specifications for Cypress Timber

All cypress timber shall be of the red cypress variety, or what is usually called "Louisiana Cypress." It shall be divided into several grades, corresponding to the above division for pine timber, in accordance with the use to which it is to be put, and shall be generally classed as merchantable heart timber, free from extensive honey-comb peck. Timber shall not be rejected on account of small wind shakes running in one direction only, provided the timber can be used so that such shakes are vertical or at right angles to the bearing faces of the timber. Timber containing extensive honey-comb peck, black, rotten knots and

[1] Disbanded and succeeded by the Southern Pine Association.

holes shall be rejected. Sap wood may be permitted in the several cases as specified above for yellow pine timber.

Specification Adopted by the Panama Canal for Southern Yellow Pine Structural Timber

Yellow pine must show on the cross section, between the third and fourth inch, measured radially from the heart center or pith, not less than six annual rings of growth, a greater number of which shall show at least one-third summerwood, the dark portion of the rings of growth. Wide-ringed material excluded by this rule will be acceptable, provided that in the greater number of the annual rings the dark ring is hard and in width equal to or greater than the adjacent light-colored ring. In all cases there must be sharp contrast in color between the springwood and summerwood.

For sizes where the center can not be determined there must show on the cross section an average of not less than six annual rings of growth, otherwise the same as the above paragraph.

In other respects to grade "Prime," Interstate rules of 1905.

Specification Adopted by the Georgia-Florida Sawmill Association for Southern Yellow Pine Structural Timber

Paragraph I.—For timbers and dimension, there must show on the cross section between the third and fourth inch, measured radially from the heart center or pith, not less than six annual rings of growth, a greater number of which shall show at least one-third summerwood, which is the dark portion of the rings of growth. Wide-ringed material excluded by this rule will be acceptable, provided that in the greater number of the annual rings the dark ring is hard and in width equal to or greater than the adjacent light-colored ring. In all cases there must be sharp contrast in color between the springwood and the summerwood.

Paragraph II.—For sizes where the center can not be determined the following will apply: There must show on the cross section an average of not less than six annual rings of growth, with not less than one-third summerwood, and otherwise as provided for in Paragraph I.

Building Code Recommended by the National Board of Fire Underwriters, New York, 1915

Rules for Grading Structural Timbers of Southern Yellow Pine, Prepared in Coöperation with the United States Forest Service

Grade I[1]

1. Requirements for Quality of Timber Based Upon Soundness and Density.

(*a*) *Soundness.*—Shall contain only sound wood.

(*b*) *Density*, as indicated by number of rings and proportion of

[1] This is practically the same as the "Select Structural" grade adopted by the Southern Pine Association.

summerwood.—Shall show on the cross section an average of not less than one-third summerwood, measured over the third, fourth, and fifth inches on a radial line from the pith. Timber averaging less than six annual growth rings per inch shall show an average of not less than one-half summerwood. Contrast in color between summerwood and springwood shall be sharp.

In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy by curvature of the rings, the inspection shall be made over 3 inches of an approximately radial line, beginning at the edge nearest the pith.

2. Restrictions on Knots in Beams.

Sound knots over 1½ inches in diameter or knots over ½ inch in diameter which are insecurely attached to the surrounding wood, shall not be permitted in the middle half of the length of narrow or horizontal faces of beams; nor in the middle half of the length of the wide or vertical faces within a distance equal to one-fourth their width from the edges (see Fig. 31). No knot shall be permitted within these areas whose diameter exceeds one-fourth the width of the face on which it appears.

The aggregate diameter of all knots within the middle half of the length of any face, shall not exceed the width of that face.

3. Restrictions on Knots in Columns.

Sound knots having diameters greater than 4 inches or one-third the least dimension of a column, or knots over ½ inch in diameter which are insecurely attached to the surrounding wood, shall not be permitted.

4. Restrictions on Shakes and Checks in Beams.

Ring shakes shall not occupy at either end of a timber more than one-fourth the width for green material, nor more than one-third the width for seasoned material. Shakes shall not show on the faces of either green or seasoned timber.

Any combination of shakes and checks which would reduce the strength to a greater extent than the ring shakes here allowed, shall not be permitted.

5. Restrictions on Cross Grain in Beams.

Shall not have diagonal grain with slope greater than one in twenty within the middle half of the length of the beam.

Grade II

6. Requirements for Quality.

Grade II includes timber rejected from Grade I on account of either (*a*) having less density than required for Grade I; or (*b*) having more serious defects than are allowed in Grade I.

(*a*) Timber rejected from Grade I because of deficient density, will be accepted in Grade II provided it meets all the requirements of Grade I, except that in Rule 1, (*b*), the requirement for one-third summerwood in material having six rings and over per inch, shall be changed to one-fourth; and that the requirement of one-half summerwood in material having less than six rings per inch, shall be changed to one-third.

(*b*) Timber rejected from Grade I for excess defects will be accepted in Grade II, provided its density conforms to Rule 1, (*b*), and its defects are limited as follows:

7. Restrictions on Knots in Beams.

Sound knots over 3 inches in diameter or whose diameter exceeds one-half the width of the face on which they appear, or knots which are insecurely attached to the surrounding wood, whose diameter exceeds 1½ inches or one-fourth the width of the face on which they appear, shall not be permitted in the middle half of the length of narrow or horizontal faces of beams; nor in the middle half of the length of wide or vertical faces within a distance equal to one-fourth their width from the edges.

The aggregate diameter of all knots within the middle half of the length of any face shall not exceed twice the width of that face.

8. Restrictions on Knots in Columns.

Sound knots having diameters greater than 6 inches or one-half the least dimension of a column, or knots insecurely attached to the surrounding wood, and having diameters greater than 3 inches or one-fourth the least dimension of a column, shall not be permitted.

9. Restrictions on Shakes and Checks in Beams.

Ring shakes shall not occupy at either end of a timber more than one-third the width for green material, nor more than one-half the width for seasoned material.

Any combination of shakes and checks which would reduce the strength to a greater extent than the ring shakes here allowed, shall not be permitted.

Grading Rules of West Coast Lumbermen's Association for Douglas Fir and Western Hemlock

Fir Timbers

Selected Common.—Shall be sound, strong timber, well manufactured and free from defects that materially impair its strength. Must be suitable for high class construction purposes; free from shake, splits, loose or rotten knots. Will allow sound and tight knots, if not in clusters, and which in no case shall exceed in diameter one-sixth the width of the face in which such knots occur up to and including 12 × 12; and further providing that such sound and tight knots in 14 × 14 and larger, shall in no case exceed 2½ inches in diameter.

The select common grade also will allow occasional variation in sawing; tight pitch pockets, not over 6 inches in length; wane not to exceed 1 inch on one corner and not exceeding one-sixth the length of the piece.

No. 1 *Common.*—Timber 6 × 10 and larger shall be sound stock, well manufactured and free from defects that will materially weaken the piece. Occasional slight variation in sawing allowed. 10 × 10 timbers may have a 2-inch wane on one corner or the equivalent on two or more corners; checks and season checks not extending over one-eighth the length of the piece. Smaller and larger timbers may have wane in proportion. In addition will allow large, sound, and tight knots which, approximately, should not be more than one-fourth the width in diameter of any one side in which they may appear; spike knots; stained sap one-third the width and slight streak of heart stain extending not more than one-fourth the length of the piece.

No. 2 *Common.*—This grade will admit large, loose, or rotten knots; a 10 × 10 may have 3-inch wane on one corner or the equivalent on two or more corners—larger and smaller sizes in proportion; shake or rot that does not impair its utility for temporary work. Hemlock and white fir will be allowed in this grade.

Interstate Rules of 1916

Yellow Pine Lumber

All lumber must be sound longleaf yellow pine. Sizes 2 inches and over in thickness and over 6 inches in width, there must show on the cross section of one end between the third and fourth inch, measured radially from the heart center or pith, not less than six annual rings of growth, a greater number of which shall show at least one-third summerwood, which is the dark portion of the rings of growth. Wide-ringed material excluded by this rule will be acceptable, provided that in the greater number of the annual rings the dark ring is hard and in width equal to or greater than the adjacent light-colored ring. In all cases there must be sharp contrast in color between the springwood and summerwood. For sizes where the center can not be determined, the following will apply: There must show on the cross section an average of not less than one-third summerwood, and otherwise as provided where the heart center or pith can be determined. Well manufactured, full to size and saw butted, and shall be free from the following defects: Unsound, loose and hollow knots, worm holes and knot holes, through shakes, or round shakes that show on the surface, and shall be square edge unless otherwise specified.

Standard.—All lumber shall be sound, sap no objection. Wane may be allowed one-eighth of the width of the piece measured across face of wane, extending one-fourth of the length on one corner, or its equivalent on two or more corners, provided that not over 10 per cent. of the pieces of any one size shall show such wane.

Merchantable.—All sizes under 9 inches shall show some heart entire length on one side; sizes 9 inches and over shall show some heart the entire length on two opposite sides. Wane may be allowed one-eighth of the width of the piece measured across face of wane, and extending one-fourth of the length of the piece on one corner, or its equivalent on two or more corners, provided that not over 10 per cent. of the spieces of any one size shall show such wane.

Prime. *Dimension Sizes.*—All square lumber shall show two-third heart on two sides, and not less than one-half heart on two other sides. Other sizes shall show two-thirds heart on faces and show heart two-thirds of length on edges, excepting when the width exceeds the thickness by 3 inches or over, then it shall show heart on the edges for one-half the length.

Working Stresses for Structural Timbers

The size of the timbers required to carry certain loads depends on the species and on the quality or grade of the timber. If specifications insuring a high quality of timber are used, it is evident that smaller sizes and higher stresses are allowable than if the specifications allow a wide variation in quality.

The working stresses in Table 11 are based on tests and grading investigations made by the Forest Service. Allowable stresses are given for timbers used under three different conditions: (*a*) damp or wet locations such as docks, piling, etc.; (*b*) outside locations not in contact with the soil such as bridges and open sheds; and (*c*) dry sheltered locations such as the interior of factories and warehouses.

The dense quality specified for southern yellow pine corresponds to Grade I timbers as given in the Building Code recommended by the National Fire Underwriters' Association. "Dense" material is also specified in the grade "Select Structural Timber" of the Southern Pine Association. The term southern yellow pine includes the principal pines of the southern States, longleaf, shortleaf, loblolly, and Cuban (slash). Since it is practically impossible always to identify the different species of yellow pine and since timbers of any of the different species may be of high grade or inferior grade, it has been recognized that the southern yellow pines should be graded on a basis of density and defects and not on a botanical basis. The same stresses

TABLE 11.—WORKING STRESSES PERMISSIBLE FOR STRUCTURAL TIMBERS

(Pounds per square inch)

	Bending				Compression					
	Allowable stress in extreme fiber			Allowable horizontal shear stress	Allowable stress parallel to grain "Short columns"			Allowable stress perpendicular to grain		
	Damp or wet location. Docks, piling, and sills	Outside, not in contact with soil. Bridges and open sheds	Under shelter in a dry location. Factories and warehouses	All locations	Damp or wet location. Docks, piling, and sills	Outside, not in contact with soil. Bridges and open sheds	Under shelter in a dry location. Factories and warehouses	Damp or wet location Docks, piling, and sills	Outside, not in contact with soil. Bridges and open sheds	Under shelter in a dry location. Factories and warehouses
Cedar, western red	750	800	900	80	650	700	700	125	150	200
Cedar, northern white	600	650	750	70	450	500	550	100	140	175
Chestnut	700	850	950	90	600	700	800	150	200	300
Cypress	900	1,100	1,300	100	800	1,100	1,100	225	250	350
Fir, Douglas (Coast Region)	1,000	1,300	1,500	95	900	1,100	1,100	225	250	325
Fir, Douglas (Mountain Region)	700	900	1,100	85	700	800	800	200	225	275
Fir, balsam	600	750	900	70	500	600	700	100	125	150
Gum, red	800	900	1,100	100	650	750	800	150	200	300
Hemlock, western	900	1,100	1,300	75	800	900	900	200	225	300
Hemlock, eastern	800	900	1,000	70	600	700	700	200	225	300
Hickory	1,200	1,500	1,900	140	1,000	1,200	1,500	350	400	600
Larch, western	900	1,100	1,200	100	800	1,000	1,100	200	275	325
Maple, sugar or hard	1,000	1,300	1,500	150	900	1,100	1,200	300	375	500
Maple, silver or soft	700	900	1,000	100	600	700	800	200	250	350
Oak, white or red	1,000	1,200	1,400	125	800	900	1,000	300	375	500
Pine, southern yellow (dense)	1,100	1,400	1,600	125	900	1,100	1,200	225	250	350
Pine, eastern white	750	800	900	85	650	750	750	125	150	250
Pine, western white	750	800	900	85	650	750	750	125	150	250
Pine, Norway	800	1,000	1,100	85	700	800	800	150	175	300
Redwood	800	1,000	1,200	70	750	900	1,000	125	150	250
Spruce, red or white	650	850	900	70	500	600	700	125	150	200
Spruce, Engelmann	500	650	750	70	450	550	600	100	140	175
Tamarack, eastern	900	1,100	1,200	95	800	900	1,000	200	225	300

may be used for Douglas fir, provided the fir is selected in a manner to insure material of corresponding quality. The other species listed in Table 11 are to include material selected under the restrictions governing defects in Grade I or Select Structural Timber. Density requirements based on proportion of summerwood have not as yet been worked out satisfactorily for these woods; in them the dividing line between summerwood and springwood in the annual rings is frequently difficult to definitely determine.

TELEPHONE POLES

The pole tests made[1] by the Forest Service had for their object a comparison of the strength of the standard pole timbers of the Western and Lake States with proposed substitutes. Standard poles of western red cedar (*Thuja plicata*) and northern white cedar (*Chamæcyparis thyoides*) were tested for comparison with poles of lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga taxifolia*), Engelmann spruce (*Picea engelmanni*), and western hemlock (*Tsuga heterophylla*).

There are at present in both the Rocky Mountains and the Coast Ranges abundant stands of lodgepole pine of little value for lumber. Lodgepole pine is not naturally durable in contact with the ground and for that reason has not been able to enter the field as a competitor of western red cedar. The general adoption of preservative treatment by railroad and telephone companies, however, has changed the situation. At an additional cost for treatment that still leaves the pine pole the cheaper of the two in most of the markets outside the region where cedar grows, the pine may be made to last longer than untreated cedar. Lodgepole pine takes treatment readily.

Engelmann spruce also has a wide distribution throughout the Rocky Mountains although it grows commercially only at the higher altitudes. It is thus not as available as lodgepole pine, nor in shape or ability to take treatment is it so well adapted for poles. It grows farther south, however, and in many districts is the only native timber available for pole use.

Forest fires in the Rocky Mountains have killed many stands of spruce and pine; and the disposal of this material, which,

[1] See *Bull.* 67, Dept. of Agriculture, "Tests of Rocky Mountain Woods for Telephone Poles," by Norman deW. Betts and A. L. Heim.

through checking, is rendered practically useless for saw timber, has always been a troublesome problem. On many areas such material remains entirely sound for a number of years after the fire, and, besides, is thoroughly seasoned and thus ready for treatment as soon as cut. In some regions the mines use all the available dead timber, though elsewhere there is a great deal of prejudice against the use of "fire-killed" material, under the mistaken assumption that there is some inherent difference

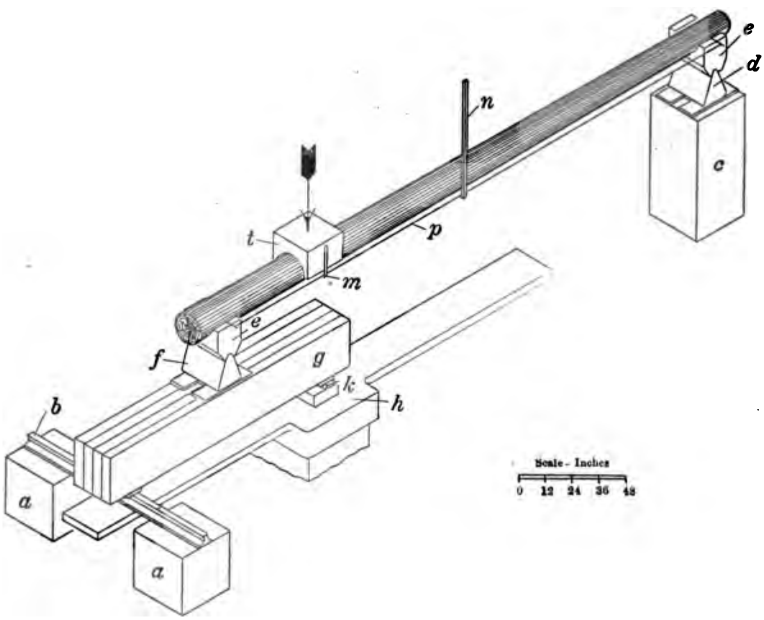


FIG. 45.—Method of testing poles.

in wood that has been seasoned on the stump and wood that has been cut when green.

Douglas fir and western hemlock poles were included in the tests because the large stands of these species in the Northwest and those of less importance in the Rocky Mountains make them competitors of western red cedar. Both northern white cedar and western red cedar in pole form are shipped over wide territories which frequently overlap, so that a comparison of the two from a strength standpoint is frequently needed.

Figure 45 shows the method used in the pole tests. The poles were supported at each end and loaded through a bearing

TABLE 12.—RESULTS OF TESTS ON POLES, SUMMAR

Length of poles

Tested over 23-foot span with supports 1 foot from
Tests made at U. S. Forest Service Laboratories

Group No.	Species and locality where grown	Condition	Number of tests		Top diameter
					Inches
1	Western red cedar—Edgemore, Idaho.	Seasoned about 3 years.	20	Av.	7.0
				Max.	7.5
				Min.	6.2
2	Lodgepole pine—Anaconda, Mont.	Seasoned 5 months.	22	Av.	7.4
				Max.	8.3
				Min.	6.7
3	Lodgepole pine—Norrie, Colo.	Had been standing fire-killed 10 years when cut.	10	Av.	7.5
				Max.	9.3
				Min.	6.8
4	Engelmann spruce—Norrie, Colo.	Had been standing fire-killed 10 years when cut.	20	Av.	7.3
				Max.	8.0
				Min.	6.0
5	Western red cedar—Washington.	Seasoned 14 months. Slight interior rot at butt.	15	Av.	7.2
				Max.	8.2
				Min.	6.6
6	Western red cedar—Oregon.	Seasoned 14 months. General decay in butt and many knots.	15	Av.	7.1
				Max.	7.7
				Min.	6.7
7	Western red cedar—Idaho.	Seasoned 1 year. Few knots, little rot.	15	Av.	7.5
				Max.	8.5
				Min.	6.9
8	Northern white cedar—Northern Minnesota.	Seasoned 2 years. Centers rotten and many knots.	15	Av.	7.5
				Max.	8.1
				Min.	7.0
9	Douglas fir—Tolt, Wash.	Seasoned 16 months. Very few knots and comparatively little taper.	15	Av.	8.7
				Max.	10.1
				Min.	7.3
10	Lodgepole pine (rough)—California.	Partially air dry.	20	Av.	7.4
				Max.	9.4
				Min.	6.4
11	Lodgepole pine (smooth) California.	Partially air dry.	20	Av.	7.3
				Max.	8.7
				Min.	6.1
12	Lodgepole pine—California.	Had been standing fire-killed 1 to 5 years.	20	Av.	7.7
				Max.	11.1
				Min.	6.3
13	Western hemlock	....	....	Av.	8.2
				Max.	11.2
				Min.	7.3

NOTE *.—The top reaction at maximum load is the pull which, if applied 1 foot from the top end, would break a pole 25 feet long set 5 feet in the ground.

GROUPS 1 to 4, inclusive, tested at Boulder, Colo. Groups 5 to 13, inclusive, tested at Seattle, Wash.

GROUP 1.—Cut near Edgemore, Idaho, winter of 1908–09. Probably peeled at time of cutting. Tested August, 1910.

GROUP 2.—Cut near Anaconda, Mont., July, 1911. Tested December, 1911.

GROUPS 3 AND 4.—Cut near Norrie, Colo. Tested 11 months after cutting.

GROUP 5.—Represents average commercial stock. Cut in Washington. Seasoned under shelter at Seattle for 14 months. Remarkably free from knots which would affect their strength. A few showed traces of interior rot at butt end.

GROUP 6.—Represents average commercial stock. Cut in Oregon. Seasoned under shelter at Seattle for 14 months. Contained many knots and almost all showed signs of decay in the heartwood.

GROUP 7.—Cut along the shore of Lake Pend Oreille. Seasoned about a year at Sand Point, Idaho, then shipped to Seattle and tested immediately. Few knots and very little rot.

IZED BY SPECIES AND CONDITION OF SEASONING
= 25 feet

each end of pole and loaded 5 feet from butt end.
at Boulder, Colo., and Seattle, Wash., 1911–1915.

Weight when tested	Moisture	Approximate age	Rings per inch	Top reaction at maximum load (See note*)	Maximum load at ground line	Bending strength: Modulus of rupture	Bending strength: Ratio to cedar (Idaho) (Group 1)	Stiffness: Stiffness factor	Stiffness: Ratio to cedar (Idaho) (Group 1)
lb.	*Per cent. of dry weight*	*Years*		*lb.*	*lb.*	*Lb. per sq. in.*			
222	15.1	84	18	2,050	11,785	6,885	100	6.75	100
259	30.8	104	22	2,948	16,940	99,360	...	9.46	...
179	12.0	55	13	1,473	8,470	5,090	...	4.43	...
304	21.9	162	34	2,250	12,930	7,680	112	8.62	127
384	34.8	170	39	3,050	17,520	9,500	...	10.80	...
248	18.5	144	29	1,770	10,190	5,190	...	6.35	...
301	16.9	155	32	1,830	10,510	5,481	80	6.25	93
412	36.2	189	42	2,840	16,320	7,480	...	8.72	...
250	11.2	97	17	714	4,110	2,230	...	4.42	...
274	16.3	164	34	1,775	10,210	4,387	64	4.97	74
332	32.8	210	46	2,652	15,250	6,070	...	6.97	...
177	11.9	112	23	731	4,210	2,180	...	3.30	...
204	14.6	60	11	1,800	10,340	6,768	98	7.54	112
272	15.9	...	..	2,890	16,600	7,620	...	8.94	...
178	13.4	...	..	1,030	5,900	4,680	...	6.45	...
264	15.7	100	18	2,370	13,610	6,038	88	6.39	95
325	16.8	...	..	2,950	16,950	8,230	...	8.18	...
213	14.8	...	..	1,930	11,100	4,580	...	5.44	...
281	20.7	136	24	2,489	14,313	6,910	100	7.03	104
350	22.8	215	36	3,230	18,570	8,260	...	9.38	...
231	18.9	63	10	1,672	9,610	5,020	...	5.12	...
341	27.1	211	29	2,152	12,374	3,540	51	3.07	45
440	40.5	325	41	2,818	16,200	4,720	...	4.07	...
293	17.8	140	19	1,564	8,990	2,540	...	2.32	...
456	18.1	61	10	4,490	25,827	9,030	131	11.55	171
583	19.5	71	12	6,300	36,220	10,290	...	15.26	...
323	17.1	55	8	2,850	16,380	6,680	...	7.60	...
437	[1]25.1	105	16	2,910	16,729	4,356	63	4.72	70
534	27.0	140	21	4,356	25,050	5,610	...	6.66	...
329	22.9	74	10	1,962	11,280	3,420	...	3.60	...
353	[1]25.2	97	17	2,572	14,791	5,597	81	6.18	92
468	29.5	126	24	3,720	21,400	8,670	...	9.34	...
259	23.0	59	10	1,640	9,430	4,460	...	4.68	...
426	28.5	101	17	2,708	15,569	4,672	68	5.57	82
680	54.9	171	26	4,920	28,290	6,610	...	7.56	...
287	20.0	64	9	1,407	8,090	2,950	...	3.60	...
401	19.5	65	12	3,890	22,369	8,250	120	10.33	153
656	22.9	81	16	6,431	36,980	10,490	...	13.37	...
321	18.1	57	9	3,066	17,630	6,040	...	7.41	...

GROUP 8.—Cut in winter along the shore of Lak Superior in Minnesota. Seasoned for about two years at Ithaca, Wis., then shipped to Seattle and tested immediately. All contained rotten centers and a great many knots.

GROUP 9.—Cut near Tolt, Wash. Seasoned at Seattle for 16 months. Particularly free from large knots and had comparatively little taper.

GROUP 10.—Rough, considered unmerchantable because of large knots and very rapid taper.

GROUP 11.—Comparatively free from large knots and judged to be of merchantable grade.

GROUP 12.—Dead from 1 to 5 years. Some quite smooth; others very rough.

GROUP 13.—

[1] Moisture determinations on only 5 poles of each of these groups (10 and 11). The poles of Group 11 were considerably smaller at the butt than those of Groups 10 and 12. Although the modulus of rupture is greater in Group 11 than in Groups 10 and 12, the maximum loads are somewhat less because of the rapid taper and consequently larger load-point diameters of Groups 10 and 12.

CAUTION.—No comparison should be made between the various groups without giving careful attention to moisture contents and descriptions of material.

block at a point corresponding to the ground line. The conditions of the test correspond rather closely to conditions of actual use where the pole is set in the ground and has to meet stresses applied by the wind to the pole through the wires and cross-arms.

Table 12 gives the results of the tests on poles. The stiffness factor is simply a factor which will enable a comparison of the stiffness of poles tested in this particular way. It can not be used to compare the stiffness of poles in other ways.

The tests on poles showed the following:

Air-seasoned lodgepole pine poles cut from live timber in Montana were fully equal in strength to the western red cedar poles tested. In actual stress developed they were superior; but on account of the greater taper of the cedar poles this advantage was lost in a comparison based on equal top diameters, the dimension usually specified.

Western red cedar poles were superior in maximum load developed to the pine and spruce poles cut from a fire-killed area in Colorado.

The fire-killed pine, after standing ten years, did not show deterioration to any appreciable extent when compared to seasoned lodgepole pine cut from representative live trees in Wyoming and Colorado.[1] The advantage in strength of the material from the lodgepole pine poles from Montana can be accounted for by the fact that it was above normal in weight.

The two shipments of western red cedar from Idaho and the shipment from Washington were practically equal in strength. The shipment from Oregon was slightly weaker.

Northern white cedar poles ranked below any others tested, both in strength and stiffness. The quality of these poles however was noticeably poor.

Douglas fir and western hemlock poles were especially strong and stiff. These poles were much heavier than the western red cedar poles.

The fire-killed lodgepole pine poles from California ranked between the other two shipments of California lodgepole pine poles in strength. Conditions of growth in lodgepole pine apparently have more influence on the strength than five years standing after being fire killed.

[1] From tests on small, clear pieces not shown in Table 12.

CROSS-ARMS

Cross-arms must resist forces which are variable in amount and direction. In a telephone line the arms may be subjected to heavy loads under several conditions:

1. If the wires on one side of a pole are broken, a heavy side pull comes on the cross-arms from the other side. This causes a severe stress in the pole, and, as will be shown later, the pole is more likely to be broken than the cross-arm.

2. If the wires are heavily covered with sleet and there is a strong wind blowing, there is a pressure on the cross-arms; but here again the stress in the pole will cause it to fail before the cross-arm will give way. Similarly, in changes of direction in the line the sidewise pull of the wires is more severe on the poles than on the arms.

3. If the cross-arms are at the same level in the line, they receive no greater strains than those which may be imposed by the weight of the wires and adhering ice and by wind pressure. If, however, the middle pole of three is higher than the poles on either side and the wires are tightly stretched, there is a strong downward pull on the cross-arm. A similar condition might result if a single pole were left standing in a line where the poles on either side had fallen.

A test was devised by the Forest Service[1] in which the load was distributed along the arm, as it is in actual practice. The load was applied vertically because the arms are likely to receive their heaviest loads in this direction and because from these results it is possible to estimate the resistance of the arms to forces acting in other directions.

The material tested consisted of 84 six-pin cross-arms 3¼ by 4¼ inches by 6 feet. These were of four species: Douglas fir, shortleaf pine, longleaf pine, and southern white cedar. The longleaf pine arms were separated into three groups according to proportion of heartwood.

The arrangement of the test apparatus is shown in Fig. 46. The stub pole "*f*" rests on a short beam on two posts, which in turn rest on the weighing platform. The pole is held in a vertical position by the columns of the testing machine. A gain about 1 inch deep is cut in the side of the pole, and the cross-

[1] See Forest Service *Circular* 204, "Strength Tests of Cross-arms," by T. R. C. Wilson.

arm is fastened into it by a $\frac{5}{8}$-inch bolt which extends through the pole.

The load is applied to the cross-arm by rods passing through the pinholes in the arm. Nuts on these rods pull down on wooden bearing blocks shaped to fit the upper side of the arm. The lower ends of these rods are attached to a system of equalizing levers (*c*, *d*, and *e*) whose arrangement is such that the rods transmit equal loads to the cross-arms.

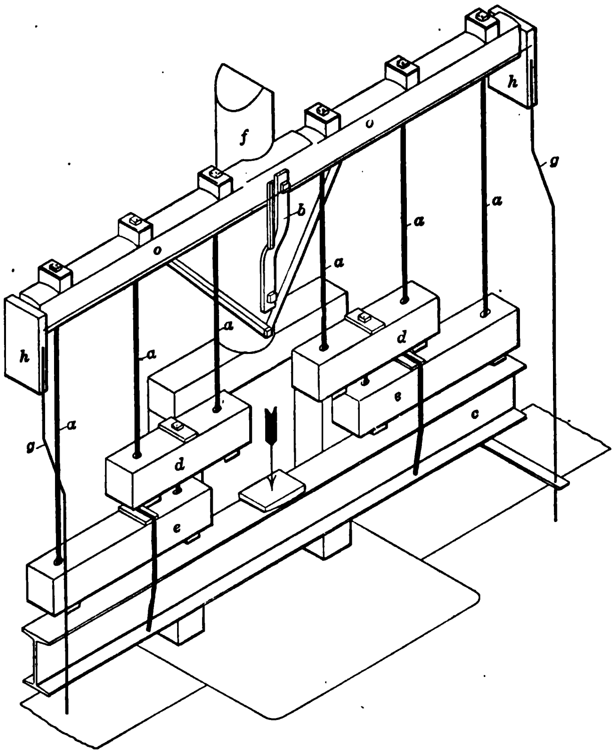


Fig. 46.—Method of testing cross-arms.

Blocks, "*h*," are each attached to the cross-arm by a nail driven into the center of its end. These blocks are held vertical by the guide rods, "*g*." A nail is driven part way into the front edge of each block and in line with the center of the cross-arm. Between these two nails is stretched a fine wire, which is kept taut by a rubber band. The movement of this wire with respect to a scale in the center of the arm marks the deflection.

A 1-inch moisture disk and an 8-inch specimen for test in compression parallel to grain were secured from each arm after the bending test was completed.

The average values from the tests are given in Table 13. The load at ½-inch deflection is an approximate measure of the stiffness. "Work to maximum load" is a measure of the toughness. The maximum load is the measure of the strength or ability to withstand a slowly applied load.

Since the longleaf pine arms with 75 per cent. of heart were stronger than those with 100 per cent., and those with 50 per cent. were weaker, other factors than the relative amounts of heartwood and sapwood must have a determining influence on the strength.

There was a very considerable difference in the strength of the natural and treated shortleaf pine arms. Just how much of this difference should be attributed to the treatment it was impossible to determine.

Both the strength values and the manner of failure show that white cedar is considerably weaker than the other species. The failure was in nearly all cases by short brash tension. The numerous small knots and the large season checks seem to have had little influence on the failures.

In many cases the principal failure was at the first pinhole from the center; and in view of this fact, particular attention should be given in grading or selecting arms, to defects near the center or the first pinholes. Knots on the upper side of the arms near these points are especially to be avoided.

The average load borne by the southern white cedar cross-arms, the weakest group, was 5,000 pounds, the load being applied vertically. Careful estimate indicates that the resistance of these arms to side pull is at least 4,000 pounds. This is more than sufficient, under any conditions of service because it is much greater than the side load that can be sustained by poles. In tests,[1] poles have not withstood an average side pull of much more than 3,000 pounds, and usually have failed at less than 2,000.

In the case of sleet or snow, if the ice coating on the wires gives each strand a diameter of 1 inch, a wind pressure of 27 pounds per square foot would be sufficient to break the pole, assuming that the poles have a resistance to side pressure of 2,000 pounds and are 150 feet apart. Even under these extreme conditions,

[1] See Telephone Poles, page 88.

TABLE 13.—RESULTS OF TESTS ON CROSS-ARMS

Eighty-four 6-pin arms—3.25 × 4.25 inches in cross section—6 feet long, 12 arms in each group

Species	Where obtained	Rings per inch	Summer-wood	Sap-wood	Moist-ure	Specific gravity (dry)	Bending tests			Compression parallel to grain
							Load at ½ in. deflection	Maximum load	Toughness (work to max. load)	Max. crushing strength
			per cent.	per cent.	per cent.		lb.	lb.	in.-lb.	lb. per sq. in.
Douglas fir	Walville, Wash.	20	40	0	11.5	0.48	4,050	7,590 (7,590)[1]	5,990	7,080
Longleaf pine, graded 50% heart	Hattiesburg, Miss.	18	44	55	13.4	0.54	4,463	8,984 (9,000)	6,888	5,425
Longleaf pine, graded 75% heart	Hattiesburg, Miss.	19	53	32	13.5	0.63	5,220	10,180 (10,240)	7,800	8,950
Longleaf pine, graded 100% heart	Hattiesburg, Miss.	16	44	1	12.8	0.63	4,770	9,782 (9,850)	7,970	8,940
Shortleaf pine	Buell, Va.	11	46	79	13.3	0.52	4,460	9,260 (9,220)	8,400	7,300
Shortleaf pine, creosoted	Buell, Va.	11	49	..	....	....	3,841	7,649 (7,360)	6,084	5,770
White cedar	Norfolk, Va.	12	45	2	14.3	0.36	2,860	5,200 (4,800)	3,150	4,700

[1] Values in parentheses are the estimated maximum loads for arms 4.10 × 3.16 inches in cross section—the average size of the Douglas fir arms.

the cross-arm would have to resist stresses equivalent to those imposed by a load of only 875 pounds, applied as in the tests, so that even the weakest of the arms tested would have more than sufficient strength to withstand a force which would break the average pole.

Where there are abrupt changes of grade in a line, as in the case of one pole being higher than those adjacent on either side, the downward pull on the cross-arm depends on the stress of the wires and their inclination from the horizontal. If six No. 8 wires are stretched to their maximum strength, assumed to be 60,000 pounds per square inch, they can exert a pull of 7,670 pounds. If a cross-arm on the middle pole had the average strength of southern white cedar, it could not be broken by such a pull unless the pole were at least 45 feet higher than the two at each side, the spans being 150 feet. Such an abrupt change in grade is rare in practice. If the cross-arm were weakened to 60 per cent. of its air-dry strength, which would correspond to a green or water-soaked condition, the arm would not break unless the difference in height were at least 25 feet.

All things considered, cross-arms of the species and dimensions tested are strong enough for ordinary use. Their strength is relatively of much more importance when they are longer. The ability of the timber to resist decay, and the methods of preventing its decay are considerations of greater importance than strength in the species and sizes tested.

PACKING BOXES

Compression and Drop Tests

In order to determine the relative ability of three styles of boxes, nailed, wirebound, and dovetailed, to stand rough usage, tests were made[1] on three sizes of each, "small," "medium," and "large." The capacity of the three sizes was, respectively, 6, 12, and 20 one-gallon cans 4 × 6 inches in cross section and 10 inches long.

Each style and size of box was tested in three ways, by endwise compression, by diagonal compression, and by dropping. The results with descriptions of the boxes are given in Table 14.

[1] See Forest Service *Circular* 214 "Tests of Packing Boxes of Various Forms," by John A. Newlin.

Endwise Compression.—In the endwise compression tests the box was compressed between two flat surfaces in the direction of its largest dimension. In this test the load which the box will stand depends largely upon the character and thickness of the material of which it is made, and the construction plays a relatively unimportant part. Most of the nailed boxes were

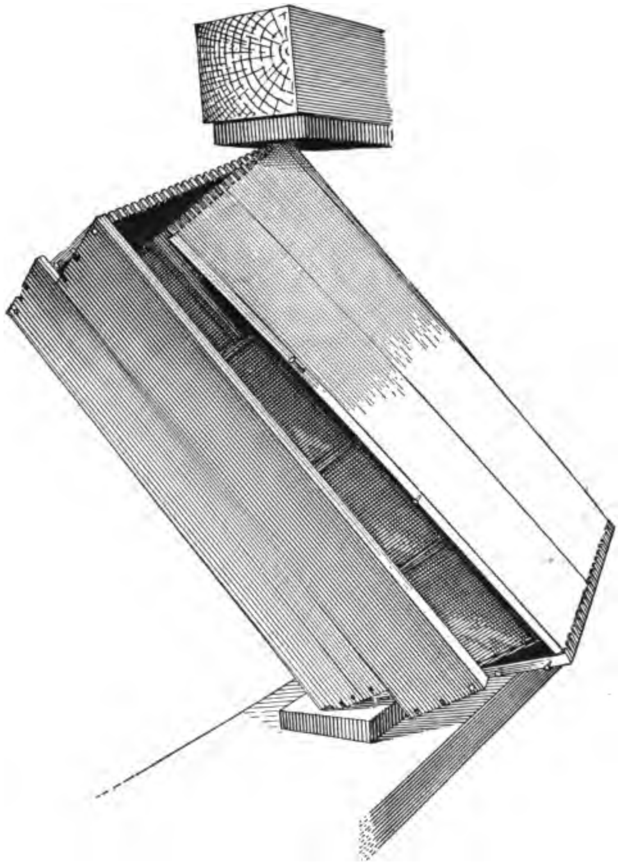


FIG. 47.—Method of conducting diagonal compression test.

constructed with two battens on each end, so that only two of the vertical faces had a good bearing. Thus the loads were less than these boxes might be expected to carry, judging from the thickness of the material. The wires of the wirebound boxes prevented buckling of the sides to a large extent and caused

TABLE 14.—RESULTS OF COMPRESSION TESTS ON NAILED, DOVETAILED, AND WIREBOUND PACKING BOXES

Class and size	Type	Weight	Material and construction	Endwise compression (2 tests averaged for each value): Maximum load	Endwise compression: Compression at max. load	Endwise compression: Toughness (work to max. load)	Diagonal compression (3 tests averaged for each value): Maximum load	Diagonal compression: Compression at max. load	Diagonal compression: Toughness (work to max. load)
		lb.		lb.	in.	in.-lb.	lb.	in.	in.-lb.
Small 8½×10¾×19 in.	Nailed	6.4	White pine: 3/8-in. sides, 3/4-in. single piece ends.	11,980	0.09	548	793	2.10	1,161
	Dovetailed	7.1	White and Norway pine: 7/16-in. sides and ends.	15,500	0.12	840	1,033	0.67	453
	Dovetailed	7.6	White and Norway pine: 7/16-in. sides, 5/8-in. ends.	18,500	0.12	1,020	1,563	1.17	1,737
	Wirebound	5.1	Red gum: 3/16-in. veneer, 4 cleats.	6,260	0.10	332	1,603	4.70	5,127
Medium 12¾×10¾×25¼ in.	Nailed	10.8	White pine: 3/4-in. ends, 2 cleats, 3/8-in. sides.	9,140	0.09	400	957	3.3	2,253
	Dovetailed	11.1	White and Norway pine: 7/16-in. sides and ends.	21,500	0.17	1,320	1,127	1.2	817
	Dovetailed	11.8	White and Norway pine: 7/16-in. ends, 5/8-in. sides.	20,750	0.15	1,350	1,567	1.87	1,967
	Wirebound	7.8	Red gum: 3/16-in. veneer, 4 cleats and 1 batten at each end	7,260	0.44	2,616	1,783	7.2	8,640
	Wirebound	10.5	Red gum: 1/4-in. resawed, 4 cleats and 1 batten at each end	11,590	0.16	1,160	1,607	4.2	4,227
Large 17×10¾×31½ in.	Nailed	25.5	White pine: 3/4-in. sides and ends, 2 cleats.	29,150	0.29	4,160	1,357	6.3	5,893
	Dovetailed	20.6	White and Norway pine: 9/16-in. sides, 7/8-in. ends.	26,550	0.22	2,675	1,985	5.9	4,055
	Wirebound	14.0	Red gum: 1/4-in. resawed, 4 cleats and 1 batten at each end.	12,000	0.23	1,520	1,930	6.2	7,873

these boxes to give results relatively high for the thickness of the material. The actual loads supported by the wirebound boxes, however, were lower than for the dovetailed and for most of the nailed boxes.

Diagonal Compression.—In the diagonal compression test illustrated in Fig. 47, the box was compressed along a line connecting diagonally opposite corners. This test produces stress in every part of the box, and the result of the test is the same regardless of which corner receives the load. The test causes failure of the box at its weakest point and thus points out the weak features of its construction. The dovetailed boxes with thick ends and the wirebound boxes withstood about the same loads. The dovetailed boxes with thin ends and the nailed boxes gave much lower values.

In shock-resisting ability, as shown by the product of the average load from 0 to the maximum and the amount of distortion or crushing, the dovetailed boxes with thin ends gave exceedingly low values. Those with thick ends gave much higher values, yet not as high as were given by the nailed boxes other than those with single piece ends. The wirebound boxes show much the highest shock-resisting ability. In stiffness or rigidity the dovetailed boxes were much superior to the others tested. This is shown by the lower values for compression at maximum load.

Drop Tests.—In the drop test the box was suspended with its diagonal corners in a vertical line and then allowed to drop 1 foot. Each drop was made 6 inches higher than the preceding one and the test continued until the cans fell from the box. Figure 48 shows the method of conducting drop tests.

Two forms of construction gave poor results, the nailed boxes with single piece ends and the dovetailed boxes with thin ends. The wirebound boxes showed great ability to withstand the drop test and were quite far ahead of the nailed boxes in this respect. The dovetailed boxes with thick ends were much inferior to the wirebound boxes and somewhat inferior to the nailed boxes with cleated ends.

The failure of nailed boxes with single piece ends without cleats shows this to be a very poor construction; 12 out of 18 such boxes subjected to drop or diagonal compression tests had both ends split completely in two. The nails driven into the ends of the boards showed very slight resistance to withdrawal. In the case of boxes with cleated ends, failures did not occur in that portion of the box. The chief source of weakness was the withdrawal of the nails holding the top. bottom, and sides to the ends.

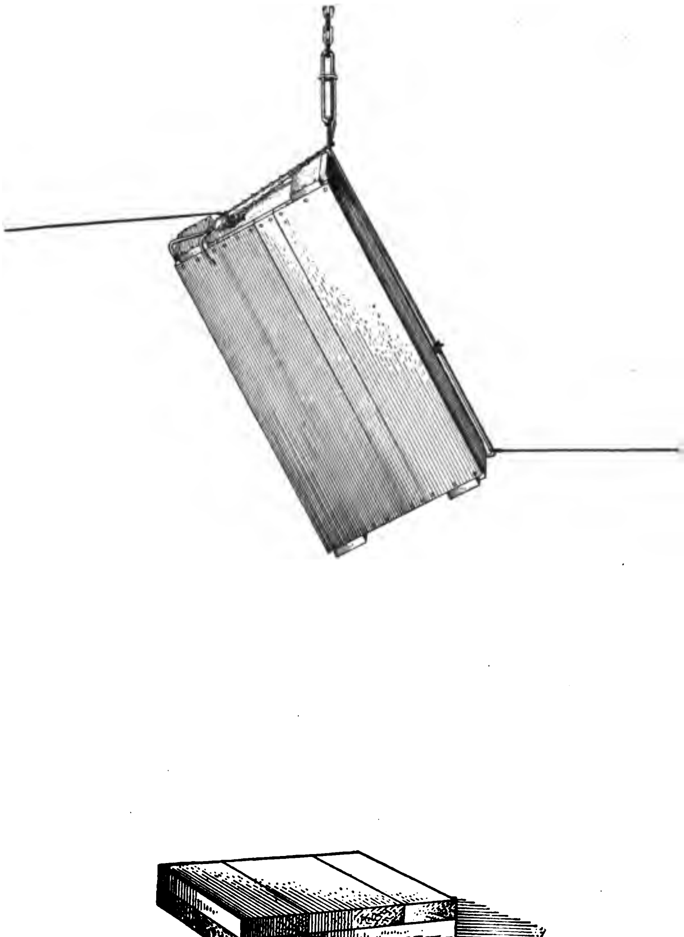


FIG. 48.—Method of conducting drop test.

An end made of thinner boards with four cleats of a wood of greater nail-holding power would probably give better results. The tests show that the single piece end is a poor form of construction and indicate the necessity of using, for certain parts, a wood that will resist the withdrawal of nails.

The wirebound boxes tested showed a well-balanced construction. The top, bottom, and sides were held firmly to the ends by the wires and by staples driven in red gum cleats. The strength of the wirebound boxes increased with the thickness of the lumber and the size of the wire. In all of the tests the wires were an important element of strength.

The thin end dovetailed boxes showed an unbalanced construction, since the joints did not hold. The thick end boxes were much better. In both cases the tongue-and-groove joints were weak features of construction. When the joints in adjacent sides and ends were in the same plane the box was materially weakened. The greater rigidity of these boxes resulted in less damage to the contents when failure occurred.

Tests by a Revolving Drum Machine

The Machine.—In order to secure a method of testing boxes by which the results could be more easily correlated with the conditions of service and by which the tests could be made in a shorter time, a revolving drum box testing machine was developed.[1] This machine consists of a hexagonal drum 4 feet long (see Fig. 49). Each of the six sides is 3 feet 6 inches long. The drum is mounted on a frame, so that it can be revolved. The inside is lined with steel and provided with fixed internal baffles or hazards which cause the box to slide from side to side of the machine and to fall in different ways on the sides, ends, and corners as the drum is slowly revolved. The speed that gives the best results has been found to be 1⅚ revolutions per minute. The machine in Fig. 49 is adapted only for boxes up to a certain size. Its operation is intended to be similar to the roughest handling which a box should receive in service and to measure ability to stand such usage. The machine does not, of course, measure the resistance of a box to static load, such as it would receive if placed at the bottom of a stack of boxes.

The Boxes Tested.—A series of tests was made on 185 nailed and 75 wirebound boxes. Part were built to hold two dozen No. 3 cans[1] and part to hold two dozen No. 2 cans.[2] The species

[1] For details of the development of this machine, see "Proceedings of American Society for Testing Materials—1916," "The Development of a Box Testing Machine and Some Results of Tests," by J. A. Newlin and T. R. C. Wilson, U. S. Forest Service.

[2] These cans are the sizes ordinarily used for tomatoes, peas, etc.

of wood used in making the boxes included white pine, southern yellow pine, yellow birch, aspen ("popple"), yellow poplar (tulip tree), and red gum.

In the nailed boxes the end construction included single piece ends, 2 piece cleated ends, 2 piece ends with corrugated fasteners,

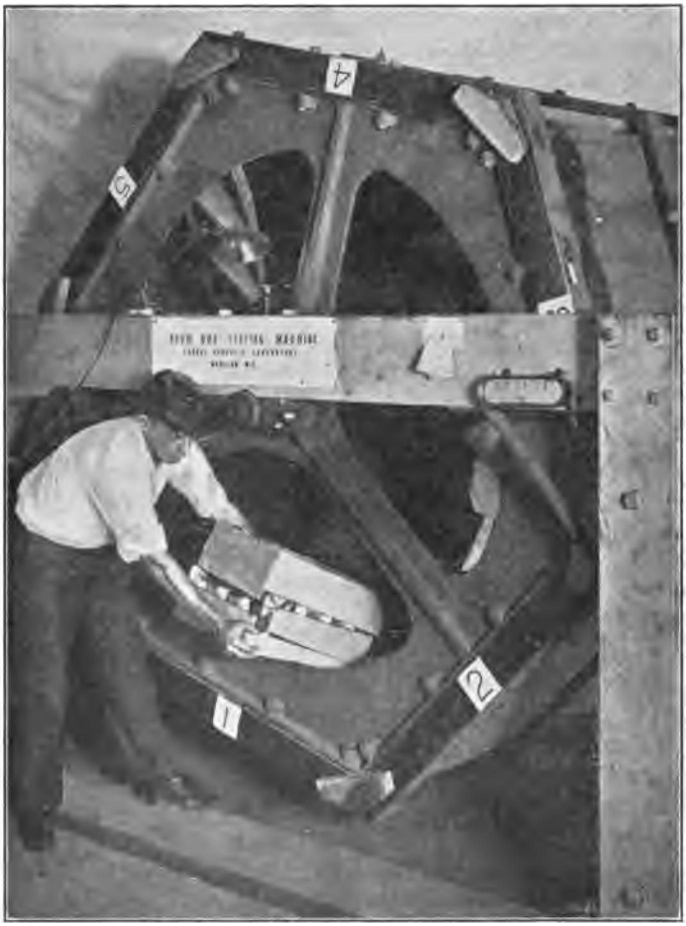


FIG. 49.—Box-testing machine.

and dovetailed ends. The thickness of the ends was ½, 9/16, 5/8, and 7/8 inch. The thickness of the sides, tops, and bottoms was ¼, 5/16, and 3/8 inch sawed lumber and 3/16, 7/32, ¼, 9/32 and 5/16 inch rotary cut veneer. The boxes were nailed with 4, 5, 6, and 7d. cement-coated nails—4 to 9 nails to the nailing edge.

The wirebound boxes were bound with No. 16 and No. 15 wires stapled with 14, 18, 20, and 24 staples per wire, and had stapled, nailed, and loose ends.

Deductions from Tests.—*Nailed Boxes.*—The tests showed plainly that the resistance of many of the nailed boxes to rough usage could be greatly increased by proper nailing. The number of nails per nailing edge proved to have a considerable influence on the resistance of the box. Figure 50 shows the relation of number of nails in the boxes to the amount of rough handling required to break the boxes. In Fig. 50 the average number of revolutions of the drum required to cause breakage and loss of contents in boxes with 7 nails per nailing edge is taken as 100.

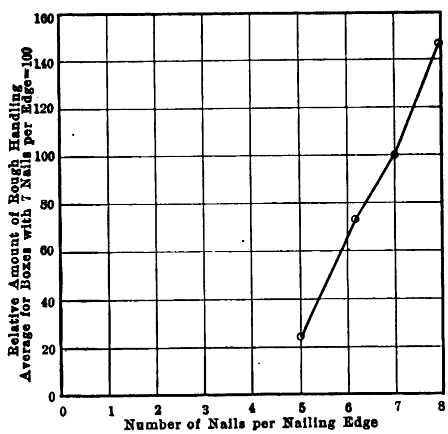


FIG. 50.—Tests on nailed boxes for two dozen No. 3 cans; relation of number of nails to amount of rough handling required to cause loss of contents.

It will be noted that boxes with 5 nails per nailing edge stood only a little over one-fifth as much as boxes with 7 nails per nailing edge. In boxes of the kind and size tested, 7 properly driven nails per nailing edge may be considered as good practice.

The single piece end without cleats was shown in the compression and drop tests to be a poor form of construction. This conclusion is further substantiated by the drum tests. The resistance of white pine, red gum, and aspen boxes with 2 piece ends was increased 50 per cent. by the substituting of cleats ($\frac{3}{8}'' \times 1\frac{1}{8}''$) for corrugated fasteners. Failure in the uncleated boxes was due to splitting of the ends, and did not occur at the joint. Similar tests on yellow pine boxes with and without cleats showed an even greater increase in resisting power in the cleated boxes.

Several cases were observed where the nails in boxes for test were over-driven. In such cases the wood fibers were crushed and damaged and the board easily separated from the nail by pulling the head through the board or pulling the board endwise from the nail. Nails driven so that the heads are flush with the surface of the boards give the best results.

In a number of boxes which were stored in a warm room before testing it was apparent that further drying had taken place, with resultant shrinkage. This shrinkage causes a side pull on the nails, which loosens them slightly. If the drying is carried far enough, splitting at the nails occurs. In either case the resisting power of the box is lowered. The storage of boxes in a warm room should evidently be avoided. It is also advisable to dry lumber for nailed boxes until it contains about 15 per cent. moisture, since this is the average condition that lumber would reach when stored in an unheated building or when in transit in closed cars.

The following classification of box woods is based on the various box tests made by the Forest Service and on the tests to determine the properties of woods, including strength, hardness, etc., and nail-holding ability.

Classification of Box Woods

Group 1.—Woods which are soft and from which nails are easily pulled. These woods require comparatively large nails. For boards ½ inch thick 5d. nails spaced 2 inches apart are suitable. For boards ⅞ inch thick 7d. nails are needed spaced 2½ inches apart.

Alpine fir	Mangolia
Aspen	Norway pine
Balsam fir	Noble fir
Basswood	Redwood
Buckeye	Spruce
Butternut	Sugar pine
Cedar	Western yellow pine
Chestnut	White fir
Cottonwood	White pine
Cucumber	Willow
Cypress	Yellow poplar
Lodgepole pine	

Group 2.—Woods which are intermediate in softness. These are the harder coniferous woods, which are more subject to shakes and checks and to splitting in nailing or from rough usage than the woods in Groups 1 or 3. These woods are also more variable in strength and nail-holding ability. Ends made of these woods are preferably cleated. Size and spacing of nails are the same as in Group 1.

Douglas fir	North Carolina pine
Hemlock	Southern yellow pine
Larch	

Group 3.—Woods which are comparatively hard and which are high in nail-holding power. These woods allow the use of smaller nails and thinner material than the woods in Groups 1 and 2. Box boards from woods in Group 3 may be 1/16 inch or 1/8 inch thinner than those from woods in Groups 1 and 2. For boards 7/16 inch thick (1/16 inch less than Group 1) 4d. nails are satisfactory. For boards 3/4 inch thick (1/8 inch less than Group 1) 6d. nails are suitable.

Ash	Maple
Beech	Oak
Birch	Red gum
Black gum	Sycamore
Elm	Tupelo
Hackberry	

Wirebound Boxes.—The tests on wirebound boxes, in which the binding wires are stapled to the sides, top, and bottom, showed that the number of staples was an important factor in the resistance of the box. In boxes with comparatively few staples the resistance of the box was lowered by the veneer tearing out from the staples. Figure 51 shows the relation of the number of staples in the boxes to the amount of rough handling required to break them. In Fig. 51 the average number of revolutions required to cause breakage and loss of contents with 24 staples per wire is taken as 100. The tearing apart of veneer and staples during the test was much less frequent in boxes with not less than 20 staples per wire. The use of staples in securing ends to cleats proved unsatisfactory, unless the staples were driven at an angle to the grain; broad-headed nails gave more uniform results.

The effect of storage conditions on boxes in which veneer was used was even more marked than on boxes made of lumber. Veneer absorbs moisture readily and dries out readily; and consequently, boxes made of veneer, if exposed alternately to humid and dry conditions, will swell and shrink and tend to loosen the fastenings. The tests indicate that the drying of veneer for boxes to about 15 per cent. moisture, as in the case of box lumber, will give the best results. The drying of veneer to considerably below 15 per cent. is of little use as the material will soon reabsorb moisture under ordinary conditions.

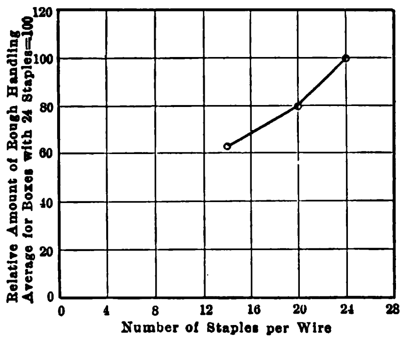


FIG. 51.—Tests of wire-bound boxes for two dozen No. 3 cans; relation of number of staples to amount of rough handling required to cause loss of contents.

WOODEN VEHICLE PARTS

The following laboratory tests[1] were made to find the relative value of different woods for vehicle parts. The material for the tests was furnished in its finished form by manufacturers and the conditions of the test were made to conform as far as possible to the conditions that would occur in actual service.

HICKORY BUGGY SPOKES

Tests were made on hickory buggy spokes to determine whether or not the system of grading was correct and to ascertain the relative strength and toughness of red and of white spokes.

The material tested consisted of 500 1-inch hickory buggy spokes. These were graded at the factory by an experienced foreman, and each grade packed separately. The different

[1] See Forest Service *Circular* 142, "Tests of Vehicle and Implement Woods," by H. B. Holroyd and H. S. Betts.

grades and the number of spokes in each, as graded at the factory in the order of their recognized commercial value, were as follows:

Grade	Number of spokes
A-white	45
B-white	45
C-white	45
C-red	45
C-mixed	45
D-white	45
D-red	45
D-mixed	45
E-white	45
E-red	45
Culls	50

The method of testing spokes is shown in Fig. 52. The

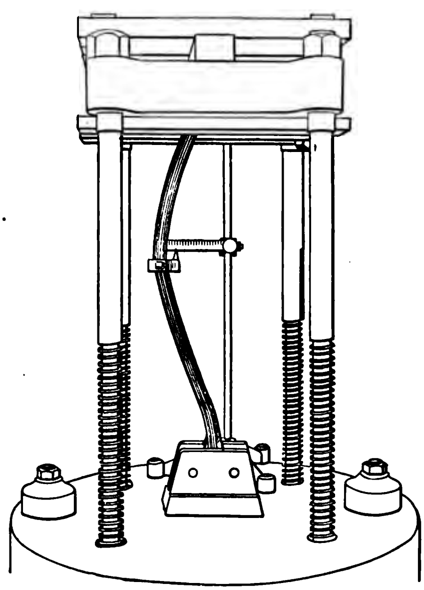


Fig. 52.—Method of testing buggy spokes.

spokes were compressed parallel to the grain and the force applied to the rim end of the spoke through the movable head of the testing machine. The spokes were cut to a length of 21 inches, the length used in the most common size of wheel. The regulation tenon was cut on the rim end, and this tenon was inserted in a hole in an iron block clamped to the movable head of the testing machine. The heel of the spoke fitted into a second iron block resting on the platform of the machine. Vertically placed in the machine, the spoke was like a column with the rim and hub ends held in the same manner as in a wheel. The amount of bending or transverse deflection at the center was shown by a pointer attached to the spoke, and arranged to move over a horizontal graduated scale. The load at the first visible failure and the maximum load were noted, together with the corresponding deflections at the center; and in each case the test was continued until the spoke had reached a deflection of 2 inches at the center. All spokes were thus subjected to the same conditions.

The factor representing the value of a spoke should include both strength and toughness. The greatest load held up by a spoke is a measure of its strength, and the amount of bending in a spoke when the first crack occurs is a measure of its toughness. The product of these two quantities gives a factor representing both strength and toughness. It is called the resilience factor.

Table 15 gives the results of the tests arranged by grades. From this table it will be seen that the average weight and the average resilience factor were both considerably higher in the A-white spokes than in the other grades. A wide range between the maximum and minimum value for the resilience factor in any grade is noticeable, showing that the quality of the spokes varied in each grade. The C-red spokes have a higher resilience factor than either the C-mixed or C-white; D-red spokes have a higher resilience factor than the D-mixed or D-white; D-red ranks ahead of C-mixed and C-white; E-white has a slightly higher resilience factor than E-red.

In investigating the relation between weight and resilience factor, only clear spokes were used. This was done in order to eliminate the influence of defects such as iron streaks, bird pecks, knots, cross grain, and wormholes. About 230 spokes were used. The weight and resilience factor of each of these spokes is plotted in Fig. 53. In this chart the weight of the spokes is shown on the horizontal scale, and the resilience factor on the vertical scale. The results of the tests, as plotted, are divided into three classes—red, white, and mixed color, distinguished on the diagram by different marks. The average points through which the heavy lines are drawn were obtained by grouping points lying between certain limits of weight. Figure

53 shows that in the case of clear spokes the resilience factor increases directly with the weight in a fairly uniform manner regardless of color and that weight for weight the red and mixed spokes have as great a resilience factor as the white spokes—that is, the red spokes and the white spokes of equal weight are equal in mechanical value.

Defects in spokes commonly include iron streaks, bird pecks, cross grain, knots, and wormholes. A spoke containing a

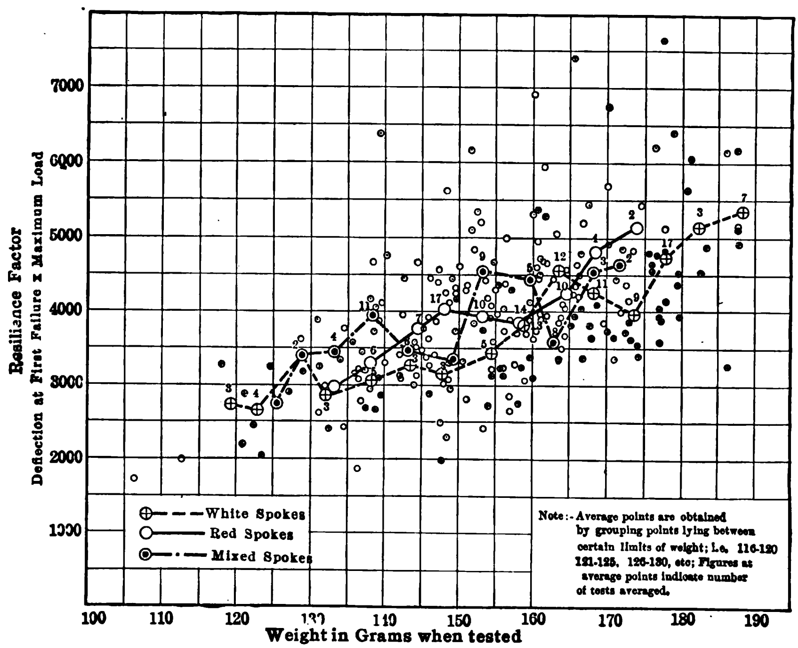


FIG. 53.—Spoke-test chart, showing relation between resilience factor and weight in clear spokes.

wormhole is dangerous, as it is impossible to tell to what extent the spoke has been bored on the inside. Iron streaks are supposed to be caused by the infiltration of foreign coloring matter through bird pecks. Iron streaks and bird pecks, when they show only slightly, apparently do not affect the mechanical qualities of a spoke. They are not generally found in the heaviest spokes, but among those of medium or light weight.

Spokes failing from cross grain generally break into two pieces. Defects have greater weakening effect when near the center than when near the ends. The spoke tests definitely show three

TABLE 15.—TESTS ON HICKORY BUGGY SPOKES
(One-inch spoke; length 21 inches.)

Grade	Weight	Maximum load	Deflection at maximum load	Deflection at first failure	Resilience factor (maximum load multiplied by deflection at first failure)
A-white:	grams	lb.	in.	in.	in.-lb.
Average	177.5	3,899	0.28	1.22	4,760
Maximum	190.3	5,005	0.50	1.75	8,080
Minimum	165.5	2,750	0.10	0.85	3,270
B-white:					
Average	164.5	3,332	0.25	1.31	4,360
Maximum	182.5	4,780	0.52	2.00	6,750
Minimum	146.0	1,615	0.04	0.72	2,740
C-white:					
Average	150.5	2,873	0.29	1.22	3,500
Maximum	182.0	4,220	0.46	1.75	6,050
Minimum	119.3	1,720	0.07	0.75	1,875
C-red:					
Average	157.2	3,080	0.28	1.36	4,190
Maximum	173.3	4,525	0.51	2.00	6,920
Minimum	144.4	1,835	0.80	0.08	2,150
C-mixed:					
Average	155.5	3,102	0.25	1.27	3,940
Maximum	186.0	4,095	0.44	2.00	8,710
Minimum	132.0	2,110	0.05	0.75	2,310
D-white:					
Average	144.2	2,815	0.28	1.13	3,180
Maximum	176.6	3,835	0.55	1.75	5,360
Minimum	118.2	2,025	(*a*)	0.65	2,045
D-red:					
Average	148.6	3,235	0.29	1.25	4,050
Maximum	174.7	4,950	0.66	2.00	5,620
Minimum	131.1	2,010	0.10	0.40	1,110
D-mixed:					
Average	145.2	3,171	0.27	1.24	3,930
Maximum	166.2	4,250	0.60	1.90	6,540
Minimum	112.8	2,065	0.02	0.70	2,000
E-white:					
Average	147.8	2,985	0.25	1.13	3,370
Maximum	174.9	4,180	0.50	2.00	5,920
Minimum	124.7	1,400	0.04	0.75	1,680
E-red:					
Average	146.1	3,009	0.24	1.08	3,250
Maximum	180.2	4,500	0.45	1.85	7,080
Minimum	106.5	2,050	0.05	0.50	1,600
Culls:					
Average	156.8	2,738	0.27	1.18	3,230
Maximum	191.4	4,025	0.50	2.00	6,200
Minimum	116.5	1,775	0.10	0.33	805

a Reading not obtained.

things: (1) That the system of grading buggy spokes did not correspond to their strength and toughness, (2) that the factor denoting the strength and toughness of clear spokes varies directly with the weight, and (3) that red, white, or mixed spokes of equal weight have practically the same resilience factor.

Oak and Hickory Buggy Shafts

The object of the buggy shaft tests was to determine the relative mechanical properties of hickory shafts graded as XX, which is a third grade, and shafts made of red oak, to show the possibilities of the latter in shaft construction.

The shafts were 1⅜ by 1⅞ inches. The stock was secured in Mississippi, about 100 miles south of Memphis, Tenn. The material was kiln dried, steamed, and bent. Ninety-two shafts were tested—46 XX hickory and 46 red oak.

The conditions under which shafts are broken in actual service are so varied that no attempt was made to reproduce any one of them exactly. The rigging for testing the shafts was arranged to hold the butt end of the shaft so that the main part projected horizontally. A vertical force was then applied near the point, and the shaft bent upward. The amount of bending or deflection near the point and the corresponding force required to produce this deflection were noted at regular intervals. The tests were continued after maximum load until there was less than 20 pounds pull on the shaft, or until the shaft came in contact with the head of the testing machine.

The weights of the two sets of shafts when dry were about the same; but the oak shafts, as they were tested, were slightly lighter than the hickory and contained 1.1 per cent. less moisture.

The oak shafts closely approximated the hickory in strength values, but at the maximum load had 7½ per cent. less deflection. In only one quality was the oak decidedly inferior to the hickory —the ability to sustain a load after failure. Thirty of the 46 oak shafts were broken in two, and only 9 sustained more than 20 pounds load at the end of the tests; only 14 of the hickory shafts were broken in two, and 24, or more than half of them, sustained more than 20 pounds at the end of the test.

A comparison of the maximum and minimum values given in Table 16 shows that the oak shafts were of much more uniform quality than the hickory, in spite of the fact that many of the complete failures in the oak shafts were due to cross or spiral grained pieces that would be eliminated by careful inspection of market material.

While these shaft tests are valuable as showing the possibility of using red oak instead of XX hickory, they can not be taken as conclusive for a number of reasons. First, the tests were too

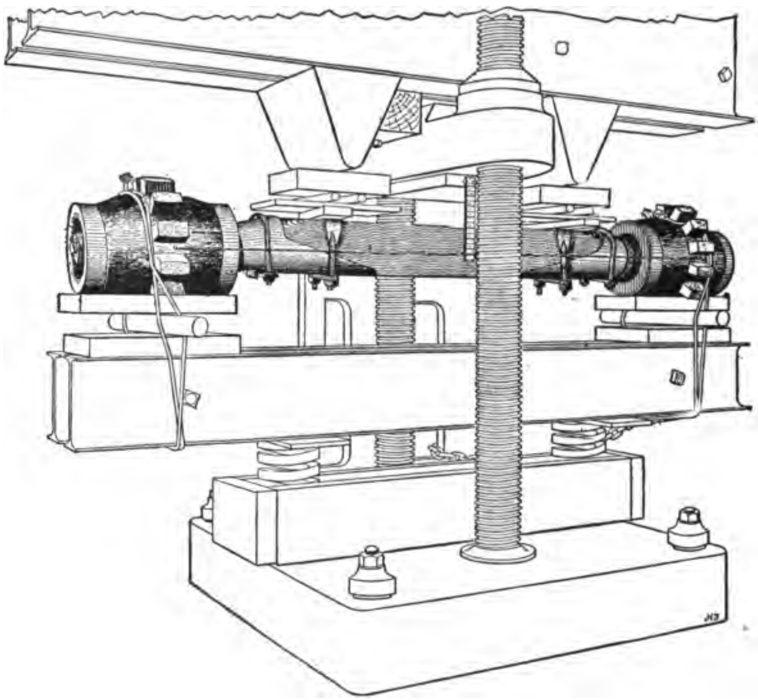


FIG. 54.—Method of testing wagon axles.

few to give sufficiently definite results. Second, the oak shafts were not as carefully selected as commercial stock should be; straight-grained material would be to the advantage of oak in comparison with the lower grade of hickory. Third, the grading of the hickory down to the XX quality was based largely on the red color, which, as shown by the spoke tests, is no criterion of degree of strength; on a strength basis some of the red hickory shafts might have belonged in a higher grade.

TABLE 16.—SUMMARY OF TESTS ON BUGGY SHAFTS

Kind of wood	Weight at test	Per cent. of moisture	Specific gravity dry	Load		Deflection		Fiber stress		Work[1] required to strain shafts to—			Stiffness factor[2]
				At elastic limit	At maximum	At elastic limit	At maximum load	At elastic limit	At maximum load	Elastic limit	Maximum load	After maximum load	
	lb.			lb.	lb.	in.	in.	lb. per sq. in.	lb. per sq. in.	in.-lb.	in.-lb.	in.-lb.	lb.
XX hickory:													
Average	4.22	10.9	0.632	65	111	10.0	30.7	6,190	10,527	335	2,264	524	53
Maximum	5.11	13.0	0.754	101	153	14.0	44.0	9,620	14,180	650	3,620	2,176	76
Minimum	3.32	9.9	0.534	42	79	7.0	17.0	3,970	7,710	151	800	0	38
Red oak:													
Average	4.19	9.8	0.627	70	122	9.9	28.4	6,474	11,318	348	2,256	295	57
Maximum	4.57	10.8	0.657	90	142	14.0	37.0	8,460	13,360	630	3,696	1,391	68
Minimum	3.97	9.0	0.597	56	100	7.0	23.0	4,640	8,130	203	1,408	0	42
RED OAK IN PER CENT. OF XX HICKORY													
	99.3	(*a*)	99.3	108	110	99	92.5	104.8	107.5	104	99.6	56.3	107.5

[1] Work, in inch-pounds, done in straining a shaft to the elastic limit, to its maximum load, and the work done beyond the maximum load in straining the shaft to the end of the test. Work is a combination of force (average load) and distance through which the force acts (deflection of shaft). The work after maximum load is a measure of the toughness of a shaft, and shows the ability of a shaft to resist shock after there is a partial failure.

[2] Stiffness factor, the load required to deflect the point of the shaft 8 inches.

a The oak had 1.1 per cent. less moisture than the hickory.

Maple and Hickory Wagon Axles

Tests were made to ascertain the relative strength of maple and hickory in the form of wagon axles, and to compare the efficiency of several styles of axle reinforcement.

The material consisted of 48 rear axles of the common farm wagon design—24 of hickory and 24 of maple. Three styles of construction were represented for each species—thimble skein, thimble skein trussed, and long-sleeve skein trussed. The axles selected were as nearly uniform in quality of wood as could be secured, and were representative of average seasoned stock.

Figure 54 shows the method of testing. The axles, with hubs placed on each skein, were mounted on two I-beams, which rested upon the platform of a testing machine. Loads were applied by the testing machine at the two hounds by means of a straining beam attached to the movable head of the machine. Heavy car springs were placed between the I-beams and the platform of the testing machine, so as to make the load follow the axles after failure occurred, and reproduce the continuous gravity action that would occur in a failure under service conditions. Rollers were used under all bearing plates in order to insure freedom in horizontal movement at the bearing points. The load was applied continuously until the maximum load was passed.

Table 17.—Strength of Maple and Hickory Axles Reduced to Same Size

Style of axle	Maple				Hickory	
	Maximum load under test	Maple in per cent. of hickory	Maximum load (adjusted to same section as hickory)	Maple in per cent. of hickory	Maximum load under test	Hickory taken as 100 per cent.
Thimble skein:	lb.		lb.		lb.	
Average	19,458	104	16,600	89	18,678	100
Maximum	24,100	120	20,600	103	20,000	100
Minimum	13,430	84	11,500	72	16,050	100
Thimble skein trussed:						
Average	23,296	109	20,500	96	21,414	100
Maximum	26,890	108	23,700	96	24,850	100
Minimum	21,240	110	18,700	97	19,350	100
Long-sleeve skein trussed:						
Average	22,601	104	22,200	102	21,760	100
Maximum	26,510	109	26,000	107	24,240	100
Minimum	17,450	92	17,100	90	19,030	100

Tables 17 and 18 give the results of the tests. An adjusted set of results was calculated because the maple axles had a slightly larger cross section than the hickory. In the table the maximum load for the maple axles was reduced so as to give the load that would be supported by maple axles of the same size in cross section as the hickory axles. In all three sets the maximum load carried by the maple axles was slightly greater than that carried by the hickory axles. The adjusted maximum load carried by the maple axles, however, was less than that carried by the hickory axles in the case of the thimble skein and the thimble-skein trussed axles, and approximately the same in the case of the long-sleeve skein-trussed axles. It is noticeable that the strength values were more constant in the hickory than in the maple axles, which indicates a greater variation in the maple stock.

TABLE 18.—PER CENT. OF MAXIMUM LOAD SUPPORTED AFTER FAILURE IN WAGON AXLE TESTS

Maple	Style of axle.	Hickory
1	Thimble skein	36
25	Thimble skein trussed	81
21	Long-sleeve skein trussed	53

The amount of bending or deflection at maximum load was greater in the hickory axles than in the maple axles in all three sets, showing the greater toughness of hickory.

The hickory axles were able to stand a greater shock than the maple axles. The load supported after failure at maximum

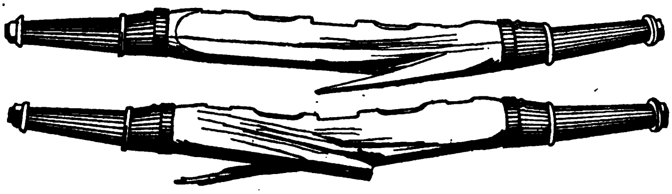


FIG. 55.—Maple wagon axles after test; thimble skein.

load was also much larger in the case of the hickory axles. When bending was continued beyond the maximum load, the maple axles had little strength left in them to support a load. The hickory axles, on the contrary, carried a large per cent. of their maximum load when subjected to the same conditions.

In the two sets of trussed axles the carrying capacity, ability to resist shock, and the load supported after failure at maximum load were all considerably greater than the same factors in the

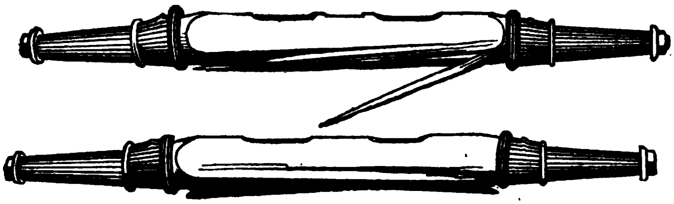


FIG. 56.—Hickory wagon axles after test; thimble skein.

untrussed axles. In nearly every case the clamp and truss slipped while the axle was under test.

In a number of axles received for test the manufacturers had

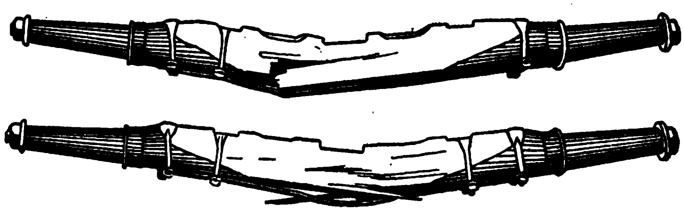


FIG. 57.—Maple wagon axles after test; long-sleeved skein trussed.

allowed the shoulder on the ends of the truss to project beyond the clamp. This allows the axle to bend considerably before the truss shoulder is pulled against the clamp and the truss

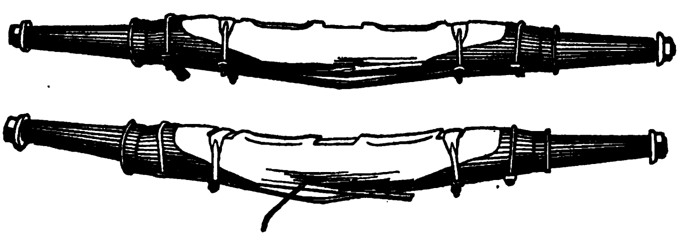


FIG. 58.—Hickory wagon axles after test; long-sleeved skein trussed.

brought into action. Out of the 32 trussed axles, in only one instance did the truss rod break.

The character of the fractures in the tested axles is shown in Figs. 55 to 58. These figures were made from photographs of individual axles taken after test. The maple untrussed axles, Fig. 55, generally failed near the center, showing a short fracture, while the failure in the hickory axles of the same design, Fig. 56, occurred near the skeins and showed a long, fibrous break.

In the trussed axles, Figs. 57 and 58, the fractures were of the same general character, although less prominent. Maple is subject to a spiral grain difficult of detection, which sometimes causes sudden and complete failure.

Oak, Southern Pine, and Douglas Fir Wagon Poles

The object of the wagon-pole tests was to check the correctness of the grading of select and common oak poles, to ascertain the utility of the truss, and to determine the value of southern pine

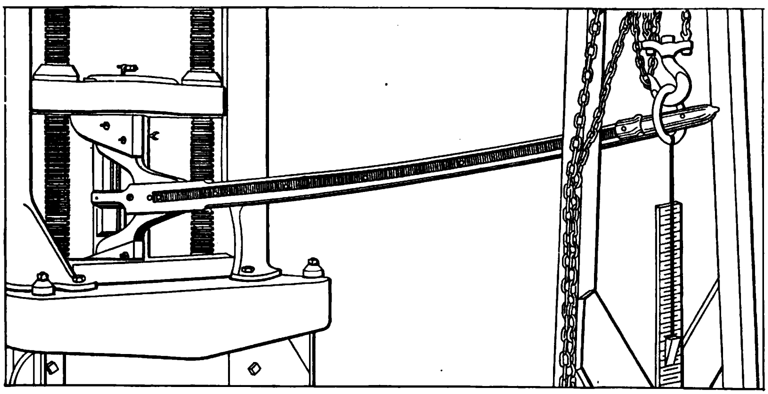


Fig. 59.—Method of testing wagon poles; trussed pole under test.

and Douglas fir for pole manufacture, as compared with oak.

The poles tested were of the common farm-wagon design and were representative of the respective grades. The following comprised the series of tests:

10 oak poles, select grade.
10 oak poles, common grade.
10 oak poles, common grade, trussed.
10 southern pine poles.
10 Douglas fir poles.

All the poles were of the same dimensions.

A device similar to the hounds on a wagon held the rear end of the pole rigid (see Fig. 59). The point of the pole was deflected by means of a tackle and suitable rigging, which transferred the deflecting load to a platform scale where it was measured. Thus the poles were tested under a strain similar to that which occurs in service when the front wheels of a wagon are blocked and the team turns sidewise.

The results of the tests are given in Table 19.

The select poles were superior to the common poles in strength, toughness, ability to resist shock, and stiffness by from 23 to 42 per cent. The poles appear to have been graded upon a correct mechanical basis.

The values for strength and stiffness were slightly higher in the case of the trussed poles. In toughness and shock-resisting ability, however, the reverse was the case. It is to be noted that more of the common untrussed poles than of the common trussed poles were cross-grained. The truss does not appear to be of any decided value from the standpoint of strength.

In maximum load and stiffness the pine poles rank between the oak select and oak common poles. In toughness and ability to resist shock the values for the pine poles are less than for either set of oak poles.

The fir poles were superior to the oak poles when not strained beyond the elastic limit. In strength and stiffness the fir ranked between the two grades of oak. The toughness and ability to resist shock was less in the fir poles than in the oak poles. The material in the fir poles was of a more uniform grade than in the oak or pine poles.

Douglas Fir and Southern Pine Cultivator Poles

Tests were made to determine the comparative value of Douglas fir and southern yellow pine for use in cultivator pole manufacture. The material consisted of 10 Douglas fir and 10 southern pine cultivator poles of the kind used in walking cultivators. The method of testing was similar to that used in testing the wagon poles (see Fig. 59).

Table 20 gives the results of the tests. There was little difference between the pine and fir poles for most of the qualities measured, but the range was much greater in the pine poles than in the fir poles. This indicates less variation of stock in the fir poles.

The load on the end of the fir poles at the elastic limit exceeded

TABLE 19.—SUMMARY OF TESTS ON WAGON POLES

Kind of wood	Weight	Load		End deflection		Fiber stress		Work[1] required to strain poles to—		Stiffness factor[2]
		Elastic limit	Maximum	Elastic limit	Maximum load	Elastic limit	Maximum load	Elastic limit	Maximum load	
	lb.	lb.	lb.	in.	in.	lb. per sq. in.	lb. per sq. in.	in.-lb.	in.-lb.	lb.
Oak, select:										
Average	38.0	394	730	14.4	41.5	6,591	11,138	2,840	19,606	313
Maximum	40.0	550	882	18.0	50.0	9,150	13,670	4,950	28,500	522
Minimum	35.5	250	550	10.1	29.5	4,170	8,820	1,263	9,100	230
Oak, common:										
Average	35.8	337	564	14.8	32.0	5,650	8,897	2,490	11,450	241
Maximum	41.3	450	882	17.3	48.0	7,550	12,800	3,380	28,100	402
Minimum	33.8	240	412	10.1	17.8	3,990	6,950	1,212	3,850	143
Oak, common, trussed:										
Average	....	374	584	15.7	30.7	6,104	9,045	2,940	10,370	253
Maximum	....	460	765	20.0	42.0	7,700	11,850	3,750	14,850	365
Minimum	....	280	400	12.6	16.8	4,490	6,350	1,760	4,050	189
Southern pine:										
Average	34.0	439	644	15.5	26.3	7,034	10,000	3,400	9,255	289
Maximum	39.8	520	735	17.4	31.5	8,260	11,300	4,160	11,650	333
Minimum	32.0	320	492	12.5	23.0	5,070	7,710	2,160	6,000	223
Douglas fir:										
Average	33.6	467	608	16.6	27.3	7,136	9,027	3,880	9,735	270
Maximum	36.3	590	683	20.7	43.0	8,950	10,050	5,690	19,550	325
Minimum	28.3	415	520	15.0	21.0	6,100	7,660	3,230	5,900	220

PERCENTAGE COMPARISON OF WAGON POLES

Oak, select		100	100	100	100	100	100	100	100	100
Oak, common		86	77	103	77	86	80	88	58	77
Oak, common, trussed		95	80	109	74	93	81	103	53	81
Southern pine		112	88	108	63	107	90	120	47	92
Douglas fir		119	83	115	66	108	81	137	50	86

[1] Work, in inch-pounds, done in straining a shaft to the elastic limit and to its maximum load. Work is a combination of force (average load) and distance through which the force acts (deflection of shaft).

[2] Stiffness factor, the load required to deflect the point of the shaft 8 inches.

that for the pine poles by 5 per cent. while the strength of the fir poles at maximum load was 5 per cent. less than that of the pine poles. The pine poles were inferior to the fir poles in stiffness, but had a greater ability to resist shock.

In both sets of poles the majority of failures occurred near the point where the pole is attached to the framework of the cultivator. In the pine poles failure was complete in 7 out of 10, the poles breaking in two. In fir poles complete failure occurred in but 3 out of 10.

Deduction from the Tests of Vehicle Parts

The foregoing tests, while in some cases only suggestive, because of the small number of samples tested, nevertheless show the value of laboratory tests as an aid in solving problems connected with the grading of vehicle wood stock, and the substitution of new species for old. The samples, representing different grades, or classes, were selected by experts with a large experience in the vehicle industries, and were thoroughly representative.

The spoke tests show an error of more than 50 per cent. in the grading system used, which was largely due to the traditional prejudice and consequent discrimination against red hickory. No red spokes were allowed in the A and B grades, yet the tests show that a large proportion of the red spokes included in the lower grades should, because of their strength and toughness, have been included in the highest grades.

The superiority of hickory in toughness and shock-resisting ability, as compared with maple, is brought out in the axle tests. It is probable that no native species combines such high values for strength, toughness, and other mechanical properties as the higher grades of hickory, which on this account are well fitted for such parts as are subjected to the greatest shock. The shaft tests indicate that red oak may be substituted for hickory of the lower grades in shaft manufacture.

The difference in toughness between oak and such woods as southern pine and Douglas fir is shown in the results of the pole tests. Both of these latter species, however, when carefully selected, appear to be promising substitutes for second-grade oak in pole manufacture.

The terms "second growth" and "forest growth" are so loosely applied in the designation of grades that they are confusing

Table 20.—Summary of Tests on Cultivator Poles

Kind of wood	Weight	Load on end of pole		End deflection		Fiber stress		Work[1] required to strain poles to—		Stiffness factor[2]
		Elastic limit	Maximum load	Elastic limit	Maximum load	Elastic limit	Maximum load	Elastic limit	Maximum load	
	lb.	lb.	lb.	in.	in.	lb. per sq. in.	lb. per sq. in.	in.-lb.	in.-lb.	lb.
Douglas fir:										
Average	20.1	305	391	14.9	20.6	9,362	11,782	2,277	4,872	220
Maximum	23.3	340	472	19.7	26.6	10,650	14,330	3,250	6,800	268
Minimum	16.5	230	308	11.7	13.0	6,810	9,650	1,580	2,240	164
Southern yellow pine:										
Average	20.6	289	413	15.9	26.1	8,535	11,682	2,300	6,654	192
Maximum	23.5	440	557	19.9	36.0	13,300	16,100	3,830	10,400	275
Minimum	15.5	160	200	11.9	13.5	4,740	5,930	952	1,640	127
Douglas Fir in Per Cent. of Southern Yellow Pine										
Southern yellow pine	100	100	100	100	100	100	100	100	100	100
Douglas fir	98	105	95	94	79	110	101	99	73	115

[1] Work, in inch-pounds, done in straining a shaft to the elastic limit and to its maximum load. Work is a combination of force (average load) and distance through which the force acts (deflection of shaft).

[2] Stiffness factor, the load required to deflect the point of the shaft 8 inches.

and might well be discontinued. These terms, as used by the trade, distinguish between good and poor wood and disregard the true meaning of the words. In order to use the terms in their correct sense, the particular species and conditions of growth would have to be known for each piece of material. Commercially this is impossible. In reality, a large per cent. of the stock which is classed as "second growth" is "forest grown" stock of good quality. As changes in the forest take place, as a result of lumbering and new growth, it may be asked at what point does the wood cease to be "forest grown" and become "second growth." The manufacturer can not definitely answer this question, and can not tell whether it may not be possible to secure both kinds of stock from the same tree.

The term "black hickory" is also confusing when used to designate a grade, because it is the accepted common name for certain species.

There is much discrimination in the trade against defects such as knots and checks, but little is said about cross-grain. The tests have continually shown that in such material as spokes, axles, and poles, cross-grain is one of the most serious defects. Defects that will be removed in finishing should not be considered defects by the inspector. Clauses in grading rules such as "Clear of any defects impairing the strength" are too indefinite.

Weight is an excellent indication of the strength of dry hickory wood, although but little used in grading rules and specifications at present. The rate of growth that generally indicates heavy and strong material and the location of such material in the cross-section of the tree are shown in the following diagrams.[1]

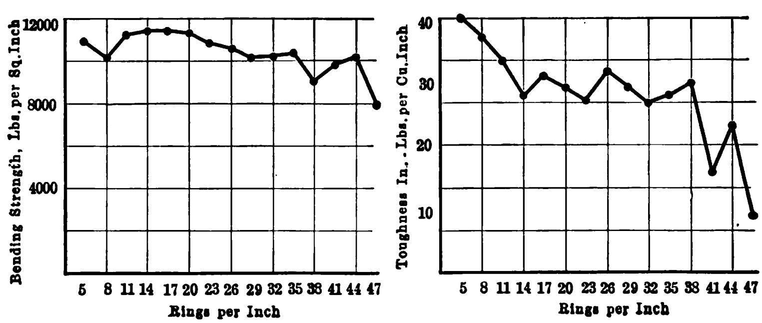


DIAGRAM 1.

[1] For a more detailed discussion of the strength of hickory see Forest Service, *Bulletin* 80, "The Commercial Hickories," by A. T. Boisen and J. A. Newlin.

The two diagrams show the variation in the strength and toughness of hickory for different rates of growth. The diagrams indicate that hickory high in strength and toughness generally has from 5 to 20 rings per inch. Exceptions exist, however, in wood grown in dry situations in which the slow growing material may be strong and tough.

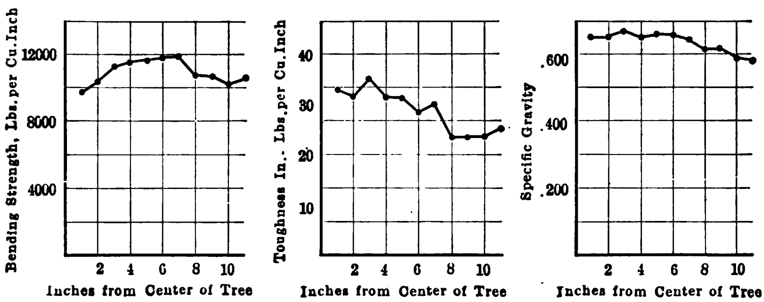


DIAGRAM 2.

The three diagrams show the variation in the strength, toughness, and specific gravity (dry weight) of hickory at different distances from the center of the tree. In normal trees the strongest wood appears to be from 5 to 7 inches from the center and the toughest wood nearly at the center. Wood 3 to 7 inches from the center is generally high in mechanical properties.

CHAPTER V

THE SEASONING OF WOOD

Importance of Proper Seasoning Methods—Fiber Saturation Point and Shrinkage—How Wood May Be Injured in Seasoning—Air Seasoning—Rules for Piling Lumber—Kiln Drying

IMPORTANCE OF PROPER SEASONING METHODS

Practically all wood before being put to use is either seasoned in the air or dried in a kiln. The main objects of seasoning are to increase the durability of the wood in service, to prevent it from shrinking and checking, to increase its strength and stiffness, to prevent it from staining, and to decrease its weight. The sooner wood is seasoned after being cut the less is the chance that it will be injured by the insects which attack unseasoned wood,[1] or that it will decay before the time comes to use it. Wood that is to be treated with preservative needs in nearly all cases to be seasoned as much as wood that is to be used in the natural state.

Wood has a complicated structure, and the walls of its cells shrink and harden when moisture is removed from them, so that unless timber which is to be air-seasoned is piled in the right way, or conditions in the dry kiln are maintained in accordance with certain well-defined physical laws, the material is likely to warp or check, or in some way to be damaged seriously. Until recently proper methods of seasoning received comparatively little attention from manufacturers; and large losses, especially among woods that are difficult to dry, were the rule. Sometimes as much as 20 to 25 per cent. of the seasoned lumber was rendered unfit for the use intended by defects which had their origin in the drying process. Since the quality of the finished product

[1] The sapwood of seasoned hardwood is subject to attack and frequently to serious damage by powder-post insects. See Farmers' *Bulletin* 778, "Powder-Post Damage by Lyctus Beetles to Seasoned Hardwood," by A. D. Hopkins and T. E. Snyder, 1917.

can be impaired seriously by wrong methods, the desirability of taking care to use right methods becomes apparent.

FIBER SATURATION POINT AND SHRINKAGE

Water exists in wood in two conditions:[1] (*a*) as free water contained in the cell cavities, and (*b*) as water absorbed in the cell

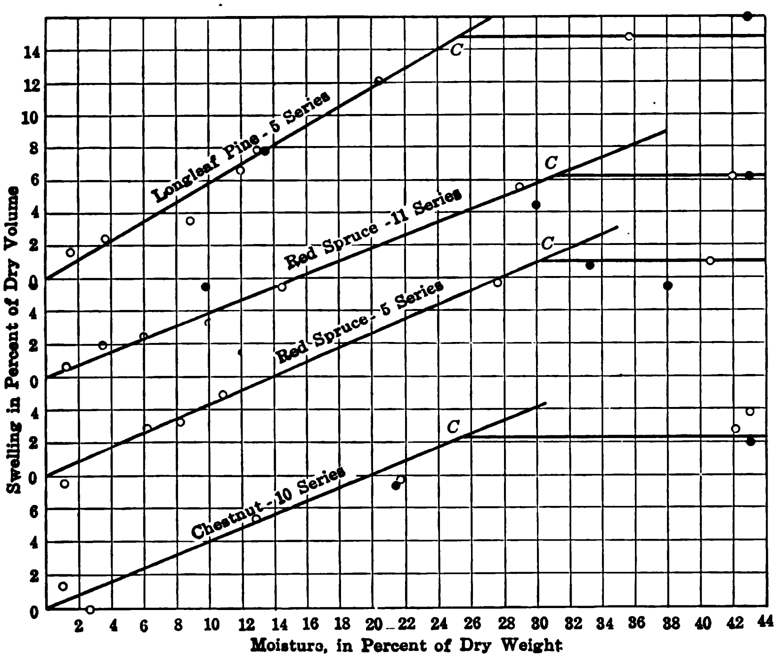


FIG. 60.—Effect of absorption of water on the volume of small, clear pieces of longleaf pine, red spruce, and chestnut. Each point is the average of from 5 to 11 specimens. The fiber-saturation point is at *C*. The black dots are for specimens that were kiln dried and allowed to reabsorb moisture.

walls. When wood contains just enough water to saturate the cell walls, it is said to be at the "fiber saturation point." Any water in excess of this which the wood may contain is in the form of free water in the cell cavities.

[1] The term "sap" sometimes is used wrongly to mean the moisture in wood, and at other times to mean the sapwood. Sap is formed, mainly in the early spring, in the leaves from water rising from the roots through the sapwood. In the leaves this water is converted into true sap, which contains sugar and soluble gums. The sap descends through the bark and feeds the tissues in process of formation between the bark and the sapwood. The heartwood contains no sap.

Removal of the free water has no apparent effect upon the properties of the wood except to reduce its weight, but as soon as any of the absorbed water is removed the wood begins to

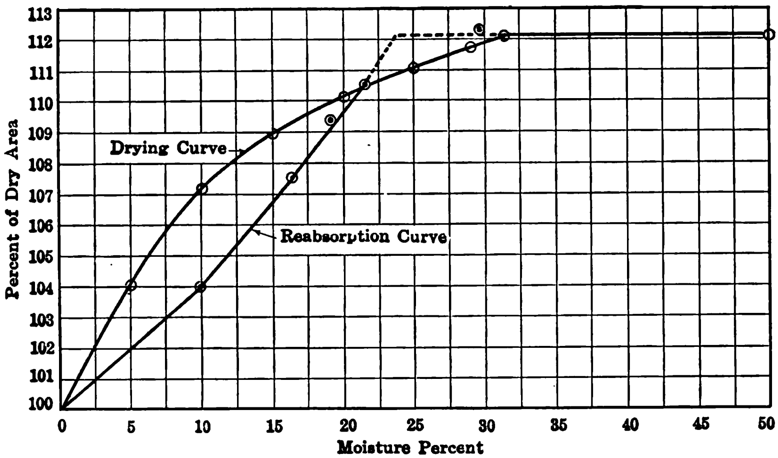


FIG. 61.—Relation between the moisture content and the cross section of small, clear pieces of western hemlock.

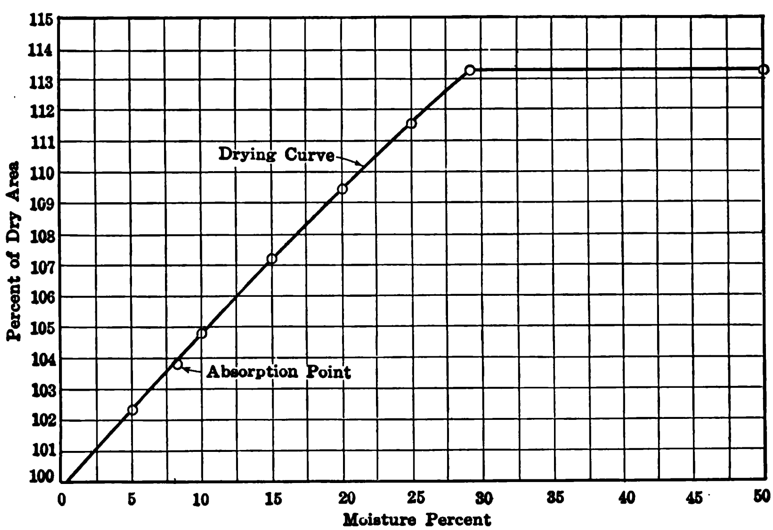


FIG. 62.—Relation between the moisture content and the cross section of small, clear specimens of western larch.

shrink. Since the free water is the first to be removed, shrinkage does not begin, as a general rule, until the fiber saturation point is reached. In the case of eucalypts and some of the oaks, however, shrinkage begins above this point. For most woods, the fiber saturation point corresponds to a moisture content of from 25 to 30 per cent. of the dry weight of the wood.

If wood below the fiber saturation point is allowed to absorb moisture, it will swell. This swelling for most woods reaches its maximum at the fiber saturation point, and further absorption of moisture has no effect on the size. Figure 60 shows the increase in the volume of several different kinds of wood when allowed to absorb moisture after first being thoroughly dried. Figures 61 and 62 show the relation between the area of the cross section and the moisture content for specimens of western hemlock and

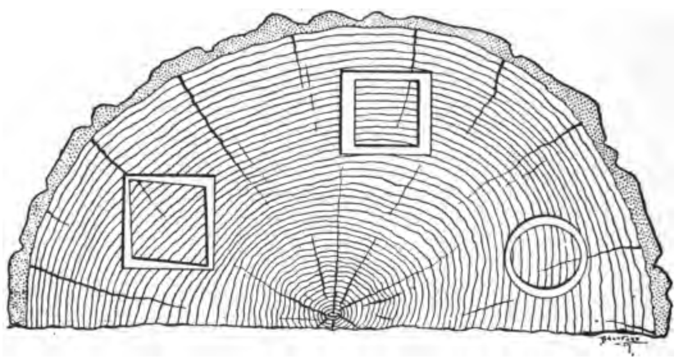


FIG. 63.—Shrinkage as affected by direction of annual rings; approximately twice as great tangentially as radially.

western larch, respectively, which were first dried out and then allowed to reabsorb moisture. Figures 60, 61, and 62 indicate that the rate of shrinkage from the fiber saturation point to 0 moisture is quite uniform and likewise that the rate of swelling from 0 moisture to the fiber saturation is quite uniform. From this it is evident that wood in an air dry condition (12 to 15 per cent. moisture) would have reached about one-half its possible shrinkage in drying from a fiber saturation point of 25 to 30 per cent. to 0 per cent. moisture.

Shrinkage is due to the contraction of the cell walls. Shrinkage of a piece of lumber in a direction tangential to the annual rings is about twice as great as in the radial direction. Lengthwise of the lumber it is very slight. Figure 63 shows graphically the difference between tangential and radial shrinkage. Table 3, Chapter II, gives the per cent. of shrinkage from a green to an oven-dry condition for the principal commercial species.

HOW WOOD MAY BE INJURED IN SEASONING

Checking.—Checking is caused by unequal shrinkage. If the outside of a piece of wood dries considerably faster than the inside, the surface in time will contract until it can no longer extend around the comparatively wet interior, and so will be torn apart in checks. Checks often are classified as end checks and face checks. End checking or splitting during seasoning causes nearly as much loss as face checking.

Casehardening.—Casehardening or surface hardening occurs when the surface of wood becomes set in a partially dry condition while the interior is still wet. This condition results from too

FIG. 64.—Sections cut from casehardened boards.

rapid surface drying. If the interior of a casehardened piece of wood dries further, it tends to shrink, while the "set" condition of the surface tends to prevent it from doing so. As a result, stresses are set up in the piece. Figure 64 shows sections cut from casehardened boards, with a strip sawed from the center of each section. In *A*, the stresses cause the prongs to curve inward and bind on the saw. If the stresses are relieved by treatment with steam, as is sometimes done, and the board dried a second time, the resawed prongs, as shown in *B*, will curve outward, owing to a reversal of the stresses. This is termed "reverse casehardening."[1]

[1] For further discussion, see "Problems in Kiln-drying Lumber," by H. D. Tiemann, Lumber World Review, September 25, 1915.

Figure 65 shows the form taken by resawed pieces of kiln-dry boards steamed for different lengths of time. In No. 1 the prongs curve inward, owing to casehardening. Nos. 2 and 3 also show a casehardened condition as indicated by the strips curving inward. In Nos. 4, 5, and 6 the casehardening has been eliminated by longer steaming and the resawed strips are straight.

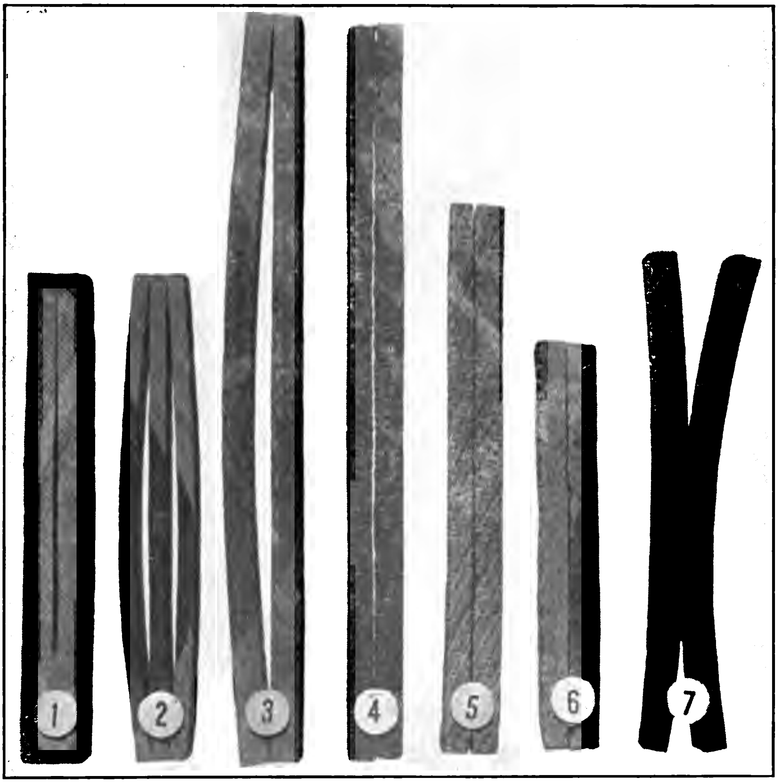


Fig. 65.—Resawed sections cut from casehardened red gum boards steamed for different lengths of time after being kiln dried. (1), No final steaming; (2) and (3), 18 minutes final steaming; (4), (5), and (6), 36 minutes final steaming; (7), 3 hours final steaming.

No. 7, which has been steamed still longer, shows a condition of "reverse casehardening," in which the resawed strips curve outward.

Sections cut as shown in Figs. 64 and 65 may be used also to determine the distribution of moisture in lumber whether casehardened or not. If not casehardened, such sections will curve inward as they dry if the lumber is wetter on the inside than on the surface, and outward if the reverse is the case. If the lumber is uniformly dry, the prongs will remain practically straight.

Honeycombing.—Honeycombing or internal checking occurs in casehardened pieces when the interior continues to dry and the surface remains fixed. In such cases splits appear in the interior. Figure 66 shows examples of honeycombing in casehardened pieces.

Warping.—Warping or twisting in lumber is due to unequal shrinkage. Some woods are much more subject to warping

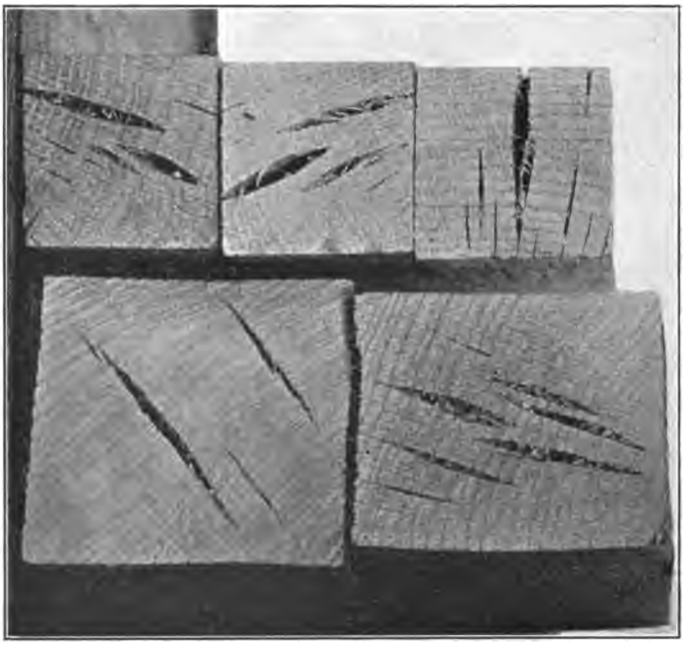


Fig. 66.—Honeycombed oak timbers, the result of casehardening.

than others. The trouble can be prevented to some extent by careful piling, both during drying and afterward. Figure 67 shows badly warped pieces of lumber.

Collapse.—In some woods, notably western red cedar and redwood, when the very wet wood is dried at a high temperature, depressions appear on the surface of the boards, presumably due to the collapse of the plastic cell walls in certain places. If, however, these woods are heated above the boiling point while wet, the steam generated in the non-porous cells causes the wood to bulge on the surface. Figure 68 shows collapse and bulging, or "explosion," as it is termed by the discoverer of the phenomenon.[1]

Brashness.—Wood subjected to high temperature treatments or very rapid drying may become brash or brittle and also darkened in color. Pieces of such wood will break suddenly when bent. Many complaints are heard of the overdrying of shingles which renders the wood brash and with "no life."

FIG. 67.—Badly warped boards. The trouble here is due to a poor arrangement of stickers and to the piling together of boards of unequal length.

AIR SEASONING

Although the use of dry kilns is increasing steadily, most wood is still seasoned in the open air. If wood is kept in the air long enough, the moisture content finally comes into equilibrium with that of the surrounding atmosphere, and the wood is said to be air-dried. The rate of drying varies, of course, with time of year, species of wood, size and form of piece, and method of piling. Certain of these factors may be controlled or utilized in a way to hasten the drying process and lessen the likelihood of defects appearing in the material.

[1] H. D. Tiemann, dry-kiln specialist, Forest Products Laboratory of Forest Service.

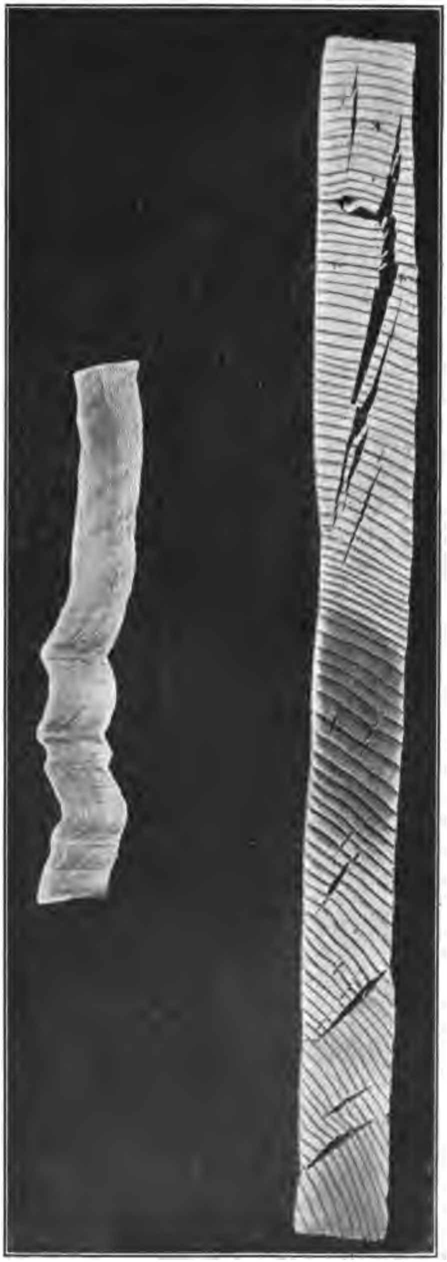


FIG. 68.—Cross section of cedar (on left) and redwood boards (on right) showing collapse and bulge respectively, in very wet lumber dried at a high temperature.

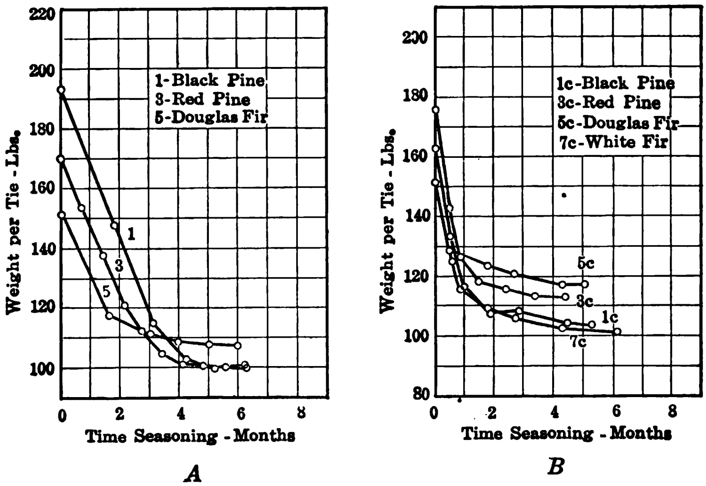


FIG. 69.—Southwestern ties. (*A*) Seasoning of ties at Pecos, N. Mex., cut in January and February. (*B*) Seasoning of ties at Pecos, N. Mex., cut in August, September, and October. (Black and red pine are local names for western yellow pine; black pine refers to young trees and red pine to mature trees.)

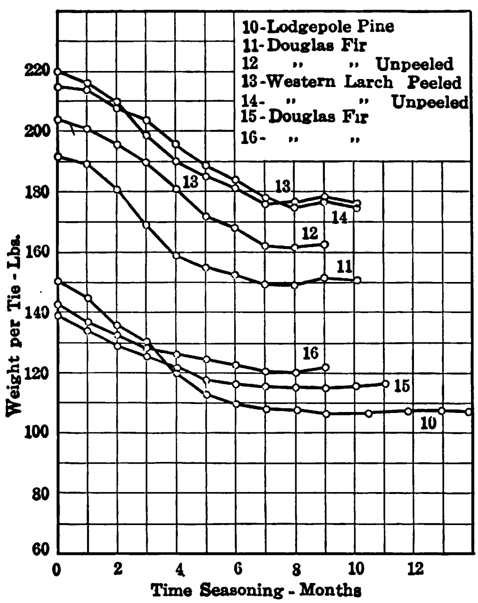


FIG. 70.—Northwestern ties. Seasoning of lodgepole-pine ties at Bozeman, Mont.; Douglas fir at Sandpoint, Idaho (curves 11 and 12); Pasco, Wash. (curve 15); and Tacoma, Wash. (curve 16); and western larch at Sandpoint, Idaho, cut in January and February; (the Tacoma ties cut in December and January).

Crossties, Poles, and Sawed Timbers.—The data in Figs. 69 to 79, inclusive, collected by the Forest Service[1] in various

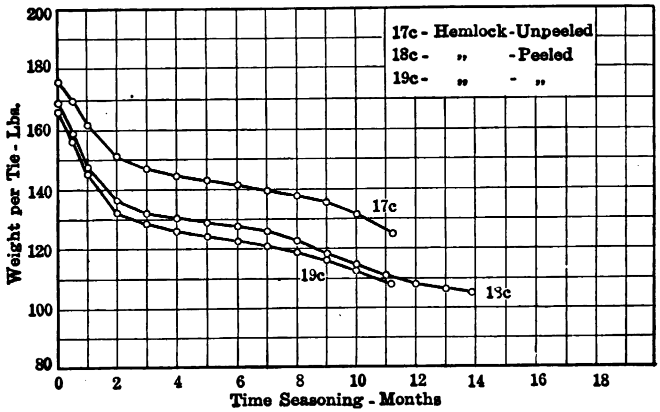


FIG. 71.—Seasoning of hemlock ties at Escanaba, Mich., cut in August and September.

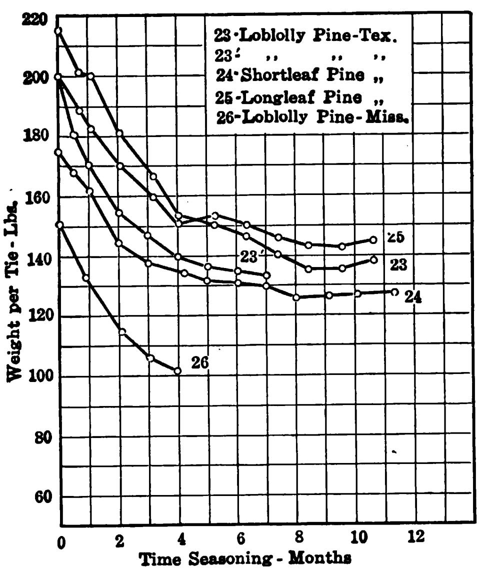


FIG. 72.—Seasoning of ties at Silsbee, Texas, and Ackerman, Miss.; cut in January and February.

parts of the country show the rate at which crossties, poles, and sawed timbers of several species lose moisture when freely exposed

[1] See "The Air Seasoning of Timber," by W. H. Kempfer, Forest Service, in *Bulletin* 161 of the American Railway Engineering Association.

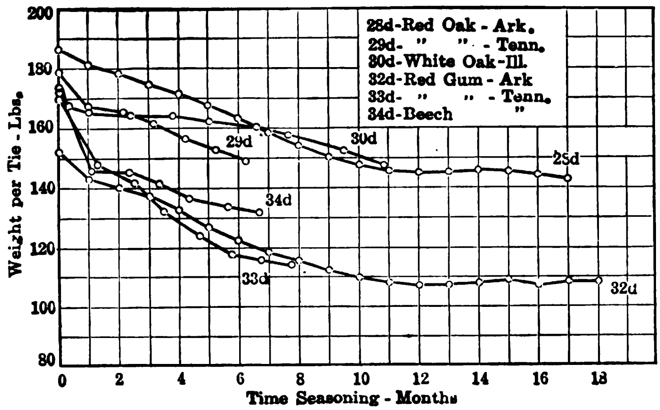


FIG. 73.—Seasoning of hardwood ties in Southern States; cut in October, November, and December.

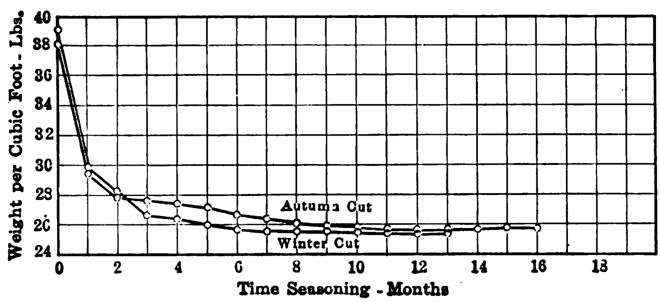


FIG. 74.—Seasoning of southern white cedar poles at Wilmington, N. C.

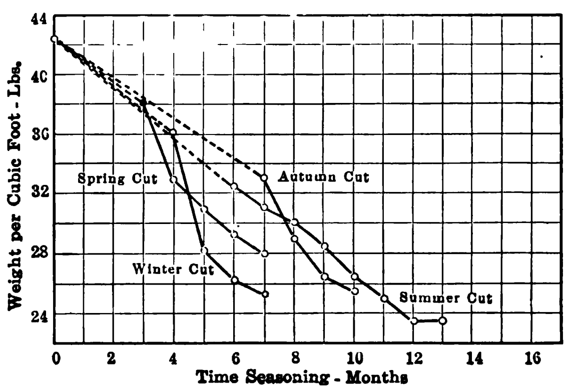


FIG. 75.—Seasoning of western red cedar poles at Wilmington, Cal.

to the atmosphere. In some cases it was not possible to weigh the pieces for several days after they were cut. Freshly cut timber loses weight very rapidly in warm, dry weather. Ties

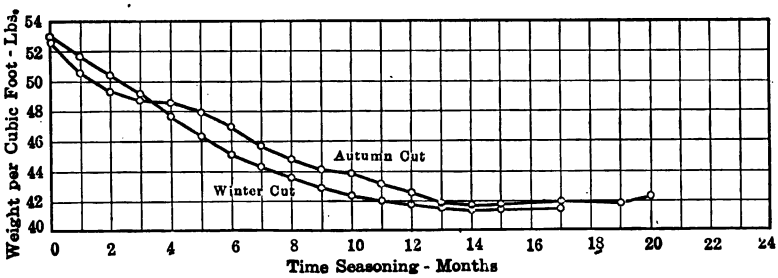


FIG. 76.—Seasoning of chestnut poles at Thorndale, Pa.

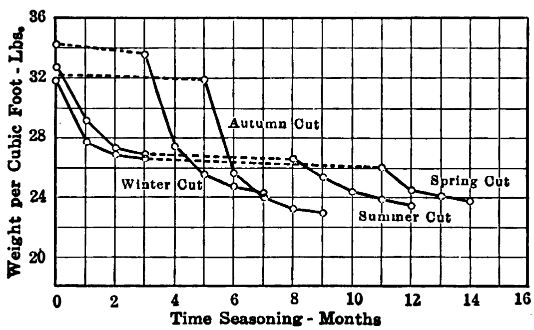


FIG. 77.—Seasoning of northern white cedar poles at Escanaba, Mich.

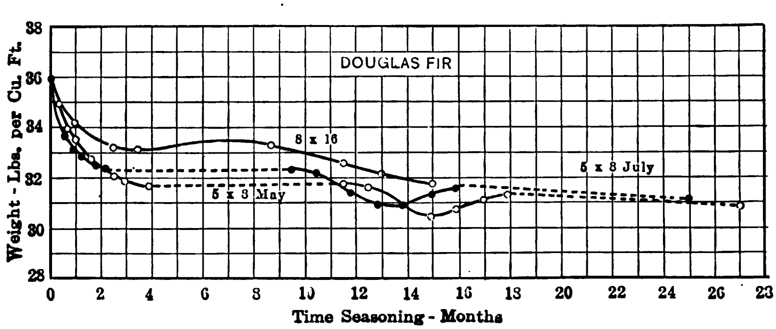


FIG. 78.—Seasoning of Douglas-fir timbers at Eugene, Oreg. (Dimensions given are in inches.)

in some species lose 10 pounds in twenty-four hours. The rates of seasoning of the various species may be compared by the general trend of the curves. When the curves reach a horizontal position, the material may be said to be air dry, unless this happens at a time of year very unfavorable for seasoning.

The ties were seasoned in piles of 50 each, and were exposed without cover. The ties on the top of each pile, however, were placed close together and served as a rough roof. The curves are plotted from the average weight of the ties. The weight per unit volume could not be used, as in many cases the volumes of the ties were not obtained. The poles were seasoned on skids in the open. The sawed timbers were seasoned in open piles under shelter.

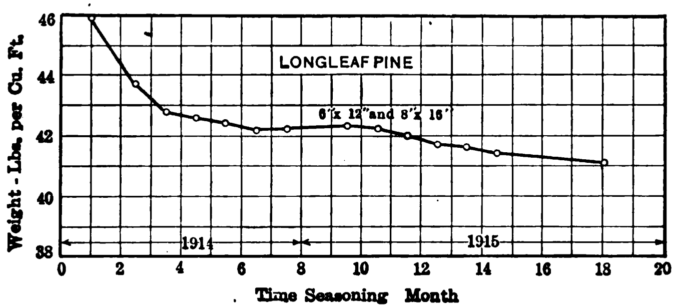


FIG. 79.—Seasoning of longleaf-pine timbers at Madison, Wis.

Lumber.—Sawed lumber is generally dried by being piled in stacks with air spaces between the boards. In forming the stacks usually the boards are laid flat, with strips called stickers between courses or layers. A space also is left between each board in a layer and the adjacent board to provide for the circulation of air throughout the stack. Flat or horizontal piling may be of two kinds: (*a*) with the ends of the boards toward the alley—endwise piling, and (*b*) with the sides toward the alley—sidewise piling. Figures 80 and 81 illustrate the two methods. The stacks are arranged to slope from front to rear, and to lean forward so that water dripping from the top falls to the ground without trickling down over the courses below. With either method of piling the stacks should be so located in the yard that the prevailing winds blow through them rather than against the sides of the stickers.

Most lumber manufacturers and dealers use the endwise method of piling. A number, however, have adopted the sidewise method, which has certain advantages in the matter of air circulation. In endwise piling the stickers obstruct the passage of air from back to front of a course, while in sidewise piling the passages from front to rear are clear. Water which forces

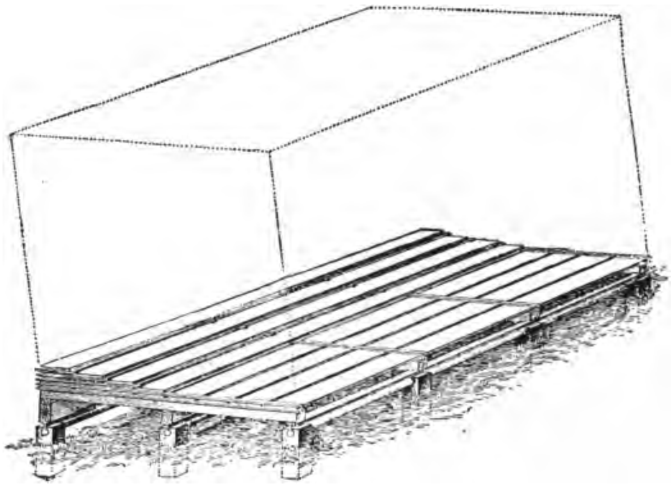


FIG. 80.—Lumber piled sidewise on cement and metal foundations.

its way into the pile is more effectively drained in sidewise piling, and the likelihood of sticker rot and discoloration due to the

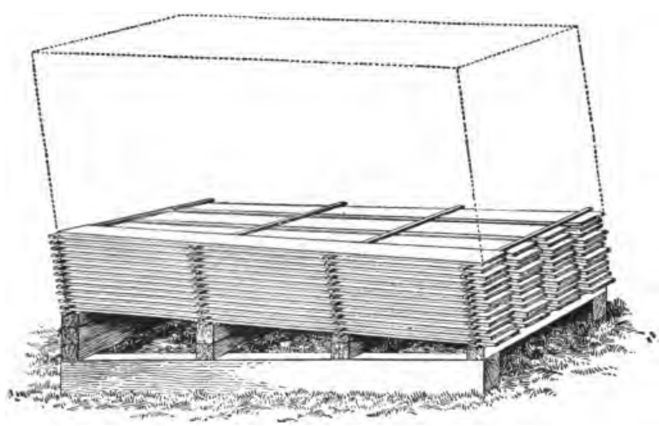


FIG. 81.—Lumber piled lengthwise on wooden foundation.

accumulation of moisture, dust, and dirt against the stickers is lessened.

The bottom boards in a stack rest on skids, which in turn rest on foundations, preferably of stone, cement, or metal. Pieces containing rot should never be used for foundation timbers or skids, or allowed to remain in the pile. The vicinity of the pile should be kept clear of weeds.

The use of concrete and metal foundations is especially feasible in retail lumber yards and in those maintained by wood-using factories. In retail yards, where economy in space often is the essential thing, the piles are high and a particular space usually

FIG. 82.—Concrete as foundation material. These blocks extend 2 feet above and 2 feet into the ground.

is allotted to each class or species of lumber. In factory yards lumber often is held for a number of years before being used. In such cases the frequent renewal of wooden foundations under lumber piles entails considerable expenditure of time and money, to say nothing of the danger of infecting lumber by bringing it in contact with partly rotted foundation timbers. For these reasons foundations of a more permanent character are constantly growing in favor in retail and factory yards. .Figures 82 and 83 show foundations of this kind.

Sawmill yards, on the other hand, often contain several million feet of material and cover several acres. Lumber coming from the saw is generally piled wherever most conven-

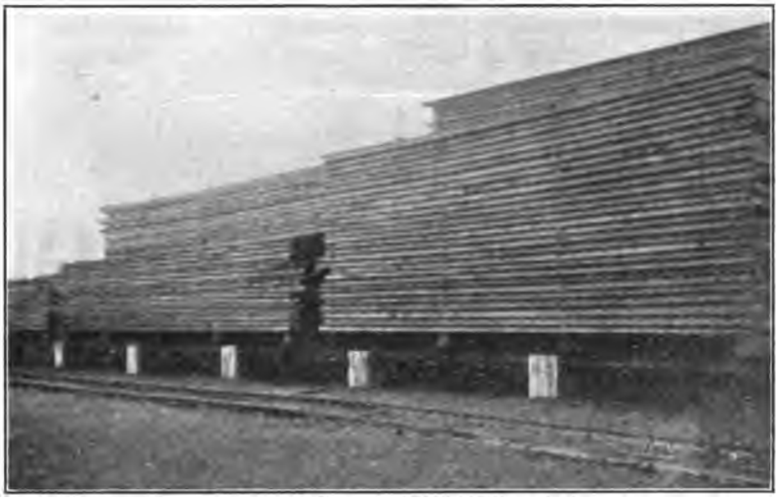


FIG. 83.—Another type of permanent foundation. Steel rails are embedded in concrete piers. The lumber is fully 2½ feet above the ground, insuring excellent ventilation.

ient, provided it is placed at the distance from the mill required by insurance companies. Usually, economy in storage space is not essential, and piles of the same species and kind of lumber are likely to be found in a number of different sections of the yard. In addition, the stock is constantly being turned over, thus giving an opportunity to renew the foundation timbers at

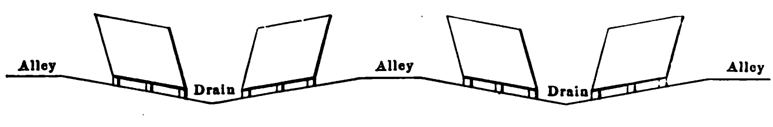


FIG. 84.—Method of providing drainage under lumber piles.

comparatively small expense. A number of large lumber companies, however, have adopted concrete as a foundation material.

Lumber-storage yards need to be reasonably well drained, or at least the contour of the ground should be such that water will not stand under the stacks after a storm. Otherwise, decay is apt to get a start and spread throughout the pile. Where the ground offers but poor natural drainage facilities, some artificial system of drainage is usually employed. Figure 84 shows the system used in the yards of two large lumber companies in the southern hardwood region. This arrangement not only prevents the collection of rain water under the lumber piles, but also gives the required slope to the stack, which on level ground has to be secured by building up the foundations. A top dressing of cinders has been found satisfactory in some storage yards.

FIG. 85.—Partially rotted hardwood boards piled against a lumber stack. Infection will spread by contact to the sound lumber.

The matter of providing good drainage in lumber yards and keeping them free from rotten pieces of lumber and tall grass and weeds is often neglected. Pieces of discarded lumber thrown aside on the ground, especially where weeds are prevalent and the ground is wet, readily develop decay-producing fungi[1] and serve as a source from which nearby stacks may become infected.

[1] See Chapter IV, Structural Timbers—Characteristics Affecting Decay in Timber.

It is not uncommon in yards to find partially rotted material piled against the lumber stacks (see Fig. 85) or to find fresh lumber stacked in direct contact with badly decayed foundation timbers. Under such conditions decay spreads rapidly to the sound lumber.

Decaying timber which has been allowed to accumulate about the yards (see Fig. 86) should be collected and burned. This will not only arrest the spread of fungi but will also lessen the

Fig. 86.—A highly insanitary mill yard in South Carolina. Hundreds of thousands of feet of stored lumber have rotted in this yard as a result of these conditions. All this rotten débris should be removed and burned.

fire hazard. The piling of such material in one place is not sufficient; for the fungi will continue to thrive in it and to liberate countless spores. These spores are blown about and find lodgement in stacks of sound lumber, where they develop and produce decay when the right conditions of temperature and moisture occur. Special attention should be paid to keeping the stickers free from infection. It is evident that the use of infected or partly decayed stickers in building up a stack of lumber is quite likely to cause decay in the lumber. When a stack is taken down, the stickers will be in much better condition for the next stack if piled on end in conical piles or stacked beneath the skids instead of being allowed to stay where they happen to fall (see Fig. 87).

In cases where lumber is stacked for a comparatively short time under conditions where it is exposed to infection, no marked deterioration may be evident. Decay may, however, be present

FIG. 87.—Piling sticks lying on the ground at a mill in South Carolina, showing the insanitary method of handling them. Such sticks lying for only a week or two in contact with fungus-infected ground may themselves become seriously infected, and may in turn pass the decay on to the lumber stacks.

in incipient stages ready to progress further should the lumber be placed under moist conditions. It is highly probable that many of the failures in timbers in important structures in recent years have been due to the use of timbers that were infected before placement in the structures. Timbers not infected are, of course, much more able to resist decay.

The railways and tramways common in lumber yards generally contain more or less rotted timber, and may become a dangerous source of infection. Little attention is paid to preservative treatment, as timber for renewals is naturally plentiful. It is well worth consideration, however, as a means of lessening the danger of infecting lumber piled for storage, as well as of reducing the frequency of renewals and the usual attendant interruptions to normal operation.[1]

Rules for Piling Lumber

The following set of rules for piling lumber covers the more important points to be observed in the construction of foundations, shape of stack, arrangement of stickers, etc.:

Foundations (Endwise or Sidewise Piling).

(*a*) The foundations should be strong, solid, and durable.

(*b*) The top of each foundation should be level, and from front to back the top surface of the parallel skids should be in alignment, so that the lumber to be piled will bear equally upon each one.

(*c*) The front foundation should be raised above the second, and the second above the third, etc., to allow a slant in the stack of 1 inch to every foot.

(*d*) The foundations should be spaced not over 4 feet apart, except for heavy planks and timbers.

(*e*) The front foundation should be of sufficient height to provide space for free circulation of air under all parts of the pile.

Lumber (Endwise Piling).

(*a*) Skids, preferably 2 by 4 inches, should be laid on top of the foundations.

(*b*) Boards of equal length should be piled together.

(*c*) The ends of the boards should rest upon the front and rear skids.

(*d*) A space of approximately three-fourths of an inch should be left between boards in the same layer.

(*e*) Lumber piled in the open should have the front ends of boards in each layer slightly protruding beyond the end of the layer beneath, to give a forward pitch to the stack.

Lumber (Sidewise Piling).

(*a*) Skids, preferably 4 by 6 inches, should be placed across the foundations at about 4-foot intervals. The number of skids depends upon the thickness of the lumber.

[1] For a further discussion of timber storage with reference to decay, see U. S. Department of Agriculture *Bulletin* 510. "Timber Storage Conditions in the Eastern and Southern States with Reference to Decay Problems," by C. J. Humphrey.

(*b*) Boards of equal length should be piled together.

(*c*) The boards should be placed on the skids, with about three-fourths of an inch between boards in the same layer.

(*d*) Lumber piled in the open should have the front board in each layer project slightly beyond the board in the layer beneath, to provide a forward pitch to the stack.

Stickers (Endwise or Sidewise Piling).

(*a*) Stickers should be of uniform thickness, preferably seven-eighths of an inch for 1-inch lumber and 1½ inches for 2-inch lumber. Their length should be a few inches in excess of the width of the pile.

(*b*) Stickers should be placed upon the layer of boards immediately over the skids and kept in alignment parallel to the front of the piles.

(*c*) The front and rear stickers should be flush with, or protrude beyond, the ends of the boards.

Roof Protection (Endwise or Sidewise Piling).

Cover boards, as a roof protection, should be laid on the top of the pile, extending a few inches beyond the front and rear ends of the stack.

Spacing Stacks (Endwise or Sidewise Piling).

Space between the piles should not be less than 2 feet; 4 or 5 feet is better if yardage conditions permit.

Dimension of Stack (Endwise or Sidewise Piling).

The customary width of stacks is from 8 to 16 feet. The height is governed by the size and character of the lumber and by the methods of moving it.

Treated Ends (Endwise or Sidewise Piling).

The ends of lumber 2½ inches thick or over, unless of the lower grades, should receive a brush treatment of paint or some liquid filler.

The rules just given are based on information obtained through field investigations and from lumber manufacturers and wholesale and retail dealers, and accord with the best lumber-piling practice in general commercial use. Certain species of wood, however, require particular care in air drying, and in this case slight variations from the rules are necessary in order to secure the best results. Some lumbermen in the South, for example, find that thick red oak checks badly on the ends, and in air-

Fig. 88.—Sun shields used to reduce checking in thick red oak timber.

Fig. 89.—Lumber piled so as to form "chimney" or flue near center of stack from bottom to top.

drying such stock have adopted the scheme of protecting it with sun shields, as shown in Fig. 88, which they claim reduces end checking to a minimum.

Mills cutting red gum formerly experienced difficulty in drying the lumber, on account of its tendency to warp. This, however, has been largely overcome by the exercise of care in seasoning. In erecting a pile of gum lumber, stickers are placed every 2 feet apart, some lumbermen claiming that 18 inches is none too close to obtain the best results. Another scheme in more or less general use among gum-lumber manufacturers is to construct the pile so as to have a flue or "chimney" in its center, thus pro-

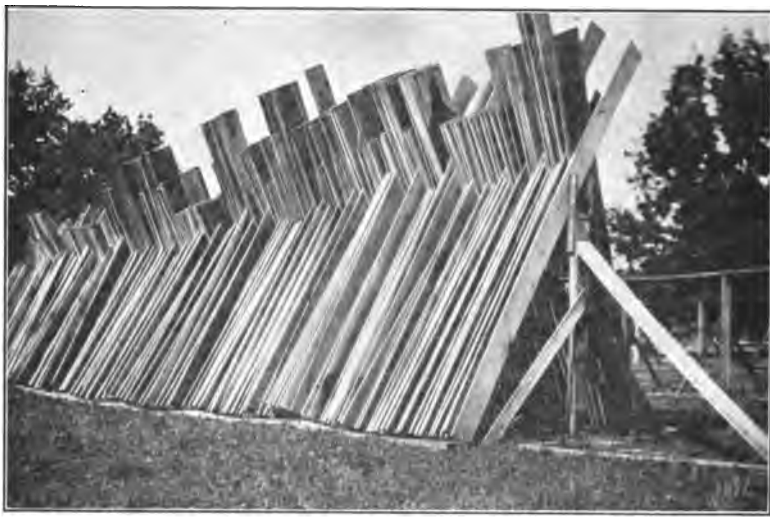


FIG. 90.—Pole drying yellow poplar lumber.

viding ample air circulation vertically through the stack, as shown in Fig. 89.

Green cottonwood, basswood, and yellow poplar lumber are likely to stain badly when piled. Accordingly, a number of lumbermen either end-dry the material or pole-dry it for a week or two and then place it in a "stuck" pile. In end drying, the boards are stood up on end, edge to edge, under a specially built shed, with stickers arranged horizontally one above the other at specified distances. Such a pile presents exactly the appearance of a regular lengthwise pile of lumber set up on end.

FIG. 91.—Pole framework used to dry yellow poplar, basswood, and cottonwood before placing it in a stuck pile.

FIG. 92.—Lumber yard of a sawmill in the Lake States. Note fine appearance of lumber piles. The discarded material in the foreground is, however, a dangerous source of infection and should be burned.

Figure 90 shows a quantity of yellow poplar lumber being pole dried; and Fig. 91 shows the frame used for the purpose.

Hickory and ash lumber frequently check badly when air dried. Lumbermen in the southern hardwood region have found that the checks will close up entirely if the lumber is first stuck piled for six to eight months and then bulk piled and protected by good covering, preferably shed. The mechanical weakening effect of such checks, however, still remains.

FIG. 93.—A well-kept lumber yard.

Figures 92 and 93 show lumber piles in yards where careful attention has been given to piling and yard arrangement.

KILN DRYING

Lumber is kiln dried when there is need for seasoning it quickly, or when the manufacturer does not wish to carry large stocks in his yard. A kiln is used also when partially air-seasoned or even fully air-seasoned material is to be dried further for special uses.

The main problem in kiln-drying lumber is to prevent the moisture from evaporating from the surface of the pieces faster than it is brought to the surface from the interior. When this is not prevented, the surface becomes considerably drier than the interior and begins to shrink. If the difference in moisture content is sufficient, the surface portion opens up in checks.

The evaporation from the surface of wood in a kiln can be controlled to a large degree by regulating the humidity, temperature, and amount of air passing over the wood. A correctly designed kiln, especially one for drying the more difficult woods, should be constructed and equipped in a way to insure this regulation.

A dry kiln may consist simply of a box in which lumber can be heated, or of a good-sized building or group of buildings (battery) containing steam pipes, condensers, sprays, and various air passages capable of adjustment to regulate the amount of ventilation. The elaborateness of the kiln depends, of course, mainly upon the value of the lumber that is to be dried. For lumber worth $100 per 1,000 board feet, it will pay to use more careful drying methods than for material valued at $20 or $25 per 1,000 board feet.

Types of Kilns.—Kilns for drying lumber may be divided into two general classes: (*a*) compartment kilns, and (*b*) progressive kilns. In compartment kilns the conditions are changed during the drying process, and all lumber in the kiln is dried at one time. The conditions at any time during drying are uniform throughout the whole kiln. In a progressive kiln conditions at one end differ from those at the other, and the lumber is dried progressively by being passed through the kiln. Compartment kilns are used when it is desired to dry lumber of various sizes and species; progressive kilns are generally used where uniform stock is handled.

The methods of operation generally used in lumber kilns are: (*a*) natural ventilation (see Fig. 94), (*b*) condensing (see Figs. 95 and 96), and (*c*) superheated steam (see Fig. 97).

In kilns operating by natural ventilation, the humidity or dampness is controlled by the use of escaping steam and evaporated moisture. Circulation in progressive kilns is largely longitudinal and in compartment kilns transverse. Moist air is allowed to escape from the kiln.

In condensing kilns the humidity is controlled by recirculating the air, which has taken up water from the lumber, across water pipes or through water sprays. The temperature of the pipes or sprays governs the amount of water that condenses from the air, and consequently regulates the humidity of the air when reheated before being passed over the lumber again. The circulation of air may be either natural or forced. Condensing kilns are generally of the compartment type.

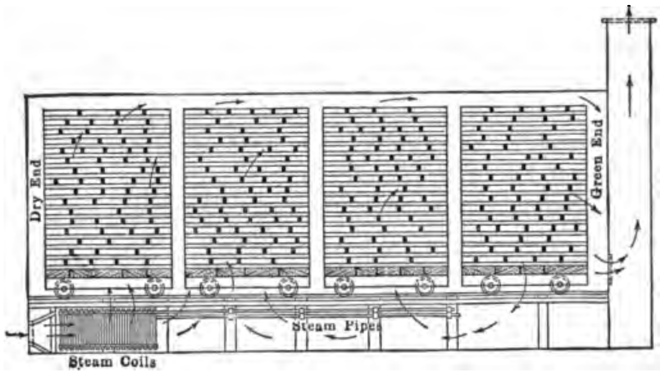


FIG. 94.—Scheme of a progressive kiln operated by natural ventilation. The entering air passes through the heating coils beneath the lumber piles then up through the lumber and out by way of the chimney. Steam may be admitted to raise the humidity.

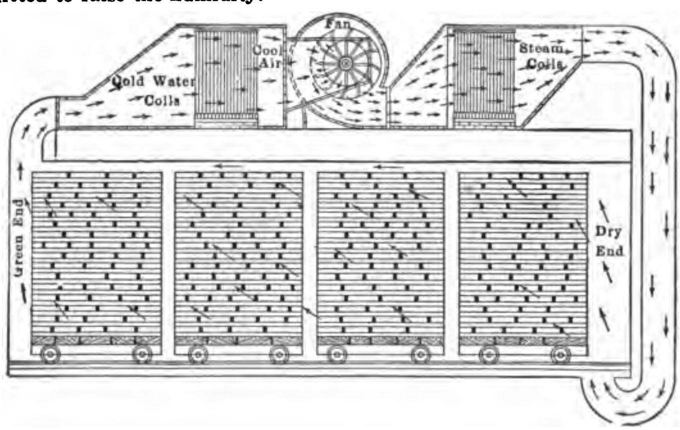


FIG. 95.—Scheme of a progressive blower kiln with a condenser for regulating the humidity. Air more or less saturated with moisture taken up in passing over the lumber is drawn from the green end of the kiln through cold-water coils, where it is cooled and part of the moisture it contains is deposited. After passing through the fan, the air is heated in the steam coils and made relatively drier. At the dry end of the kiln this heated air passes over lumber already partially dry and gradually removes moisture until the proper degree of dryness is reached. When this occurs the lumber truck at the dry end is removed and a truck with green lumber run in at the green end. By varying the temperatures in the cooling and in the heating coils the conditions in the kiln may be regulated.

Kilns operating with superheated steam are used only where the species to be dried are not injured by high temperatures and where fast drying is advantageous.

Lumber may be piled on the trucks which carry it into the kiln in any one of three ways (Fig. 98): (*a*) flat or horizontal, (*b*) edge or vertical, and (*c*) inclined. Flat piling is best for longitudinal circulation. It is not so well adapted for transverse circulation, and is not economical for downward circulation. Vertical piling increases the truck capacity, as there are no

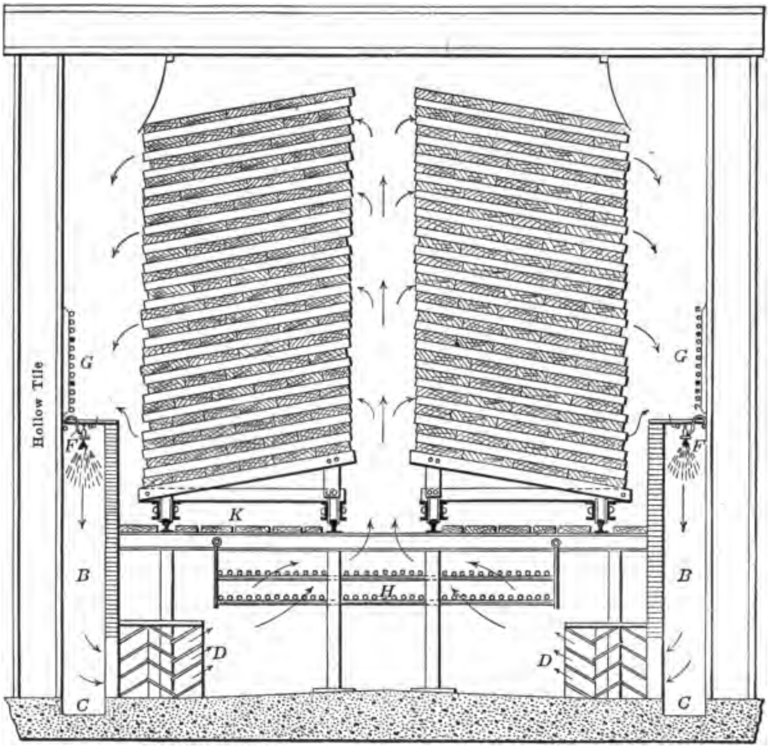


Fig. 96.—Cross section of compartment spray kiln developed by U. S. Forest Service. The air is heated by the coils (*H*), rises between the piles, and passes through them, taking up moisture from the wood. The cooled and heavier air then flows downward through the spray (*F*) and the flue (*B*) and then through the baffle plates (*D*) to the heating coils again. The condenser (*G*) is available if necessary. The temperature and velocity of the spray, the temperature of the heating coils and condensers, and the method of piling the lumber can be regulated to obtain the proper conditions for drying. It is frequently desirable to leave a space between boards in the same layer instead of placing them close together as shown.

vertical spaces between the boards. Probably it is the best method for downward or any fast circulation. Provision has to be made, however, for keeping the boards in place in the stack. Inclined piling allows for a definite movement of air either downward or upward (forced draft) and is in many cases an improvement, as regards circulation, over horizontal or flat piling.

Some kiln operators using the flat or horizontal method of piling report excellent results from the construction of a V-shaped opening in the center of the truck pile. Such openings are from 2½ to 3 feet wide at their base, and from 3½ to 4 feet high. Where this practice is followed it is customary

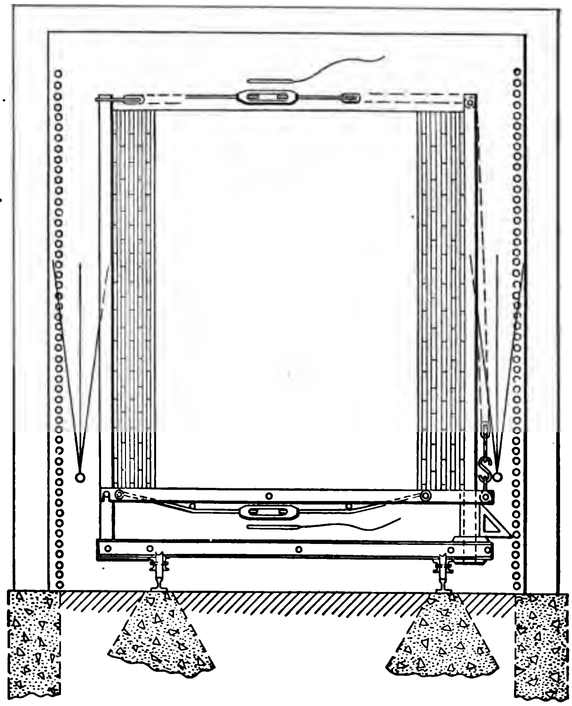


FIG. 97.—Cross section of a compartment kiln operating with superheated steam. Edge stacking with a device for taking up shrinkage is shown. Heating coils are located on each side of the kiln. Steam is admitted between the pile and the coils. The circulation is down through the pile and up on each side. The temperature and quality of steam and the temperature of the heating coils can be regulated to obtain the proper conditions for drying.

also to place the boards in the layers closer together as the top of the stack is reached, to force greater lateral circulation.

In loading lumber on kiln trucks by any one of the three methods mentioned, the stickers should be of a uniform thickness and arranged in the piles in alignment.

It is advisable not to attempt to dry various thicknesses of lumber together. Thick lumber takes longer to dry than thin lumber; and when different thicknesses are mixed the operation

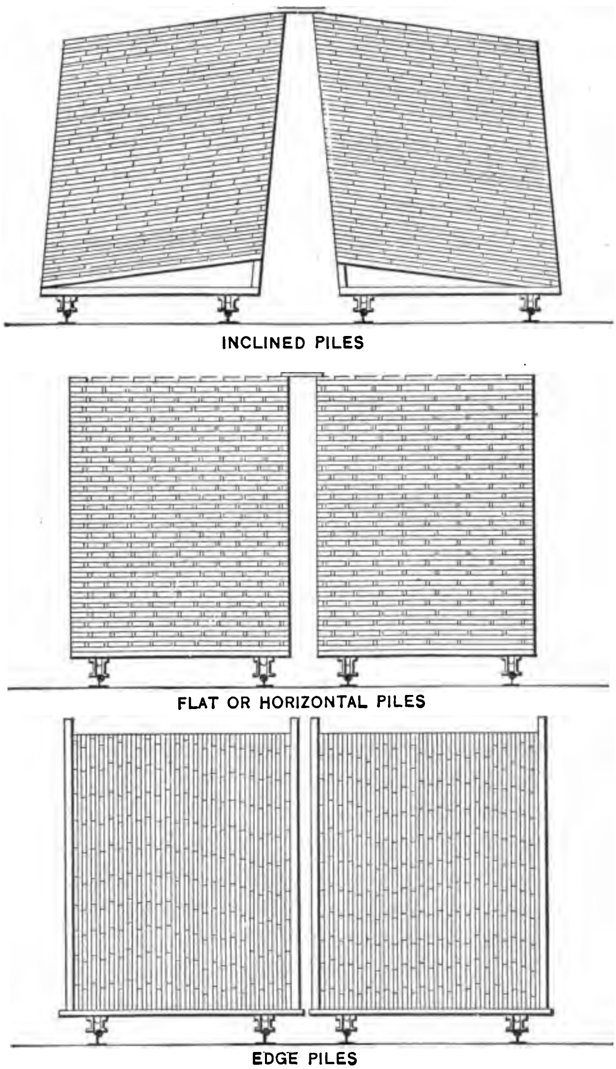


FIG. 98.—Methods of piling lumber for kiln drying.

has to be governed by the thick stock, to the possible detriment, or at least the unnecessarily long drying, of the thin stock.

Preliminary Treatments.—Lumber to be kiln dried is sometimes steamed in a separate compartment before being placed in the kiln proper; especially where the kiln is not designed for moist-air treatment. The object of the steaming is to heat the lumber and thus make easier the transmission of moisture from the interior to the surface, and also to moisten the surface in case it has become casehardened or "set" during partial air drying. Other effects, also, are produced, which to a greater or less extent change the properties of the wood. Changes of a chemical nature apparently take place; for example, "sap" is changed by "cooking," as indicated by a darkening of the wood, the degree of coloring depending upon the temperature and duration of the process.

The pressure and duration of steaming desirable in kiln drying have not yet been thoroughly worked out. Durations of from five minutes to twenty-four hours or longer and pressures ranging from atmospheric to 50 pounds gauge have been used in practice. The higher the pressure the greater is the effect produced, and the longer the time the more thoroughly the treatment penetrates the wood. Experiments have shown that a pressure slightly above atmospheric for twenty-four hours will slightly darken 2-inch maple clear through, and a pressure of 40 pounds will turn oak and probably other hardwoods almost black. Even where the strength of the wood is not the primary consideration, it probably is not safe to exceed 15 pounds gauge pressure (250° F.), except for special purposes.

In transferring lumber from a compartment for preliminary treatment to the kiln proper, every care must be used to avoid a sudden change in humidity.

The Process of Drying.—After the wood has been heated thoroughly in a humid atmosphere, either in the kiln proper or in a separate compartment, it is ready to have the moisture removed by evaporation from the surface.

In kiln drying, uniform circulation apparently is the most important thing to be secured. The fact that air when it enters the drying chamber will be cooled, and therefore will tend to fall, should govern the method of piling and the directions of circulation.[1] This means that the air should be allowed and assisted to pass downward through the pile, either by entering at the

[1] See "The Circulation in Dry Kilns," by H. D. Tiemann, U. S. Forest Service, Lumber World Review, May 10 and June 10, 1916.

top of the pile or by an adaptation of this principle to other methods of piling.

The rate of evaporation may be controlled best by regulating the amount of moisture in the air (relative humidity) circulating about the lumber in the kiln; it should not be controlled by reducing the air circulation, since a large circulation is needed at all times to supply the necessary heat. Air at 100 per cent. relative humidity contains all the water it can carry and has no effect in drying wood. If, however, the humidity is reduced to 80 per cent. and the air then passed through a pile of wet lumber, the air can take up a certain amount of moisture. If drying does not progress rapidly enough with the circulating air at 80 per cent. humidity, it may be reduced still further. This may be accomplished by ventilation, by condensers, by water or steam sprays, or in a number of other ways. If checking begins during the drying process, the humidity should be increased until it stops. Steam jets in a kiln are often useful for this purpose. In changing the humidity, the circulation should not be reduced. A large body of moving air is necessary in order to keep a uniform temperature clear through to the center of each piece of wood in the pile and at the same time supply the heat required for evaporation. If sufficient circulation is not secured, the supply of heat for both purposes will be lacking and the material will not dry uniformly.

The conditions suitable for drying lumber of a certain kind are dependent on the use to which the wood is to be put. For some purposes a decrease in strength due to rapid drying is allowable so long as the appearance of the wood is not harmed and it stays in place and does not check. Inside finish, siding, and certain kinds of furniture are examples. For other purposes, such as airplane, vehicle, and handle stock, the full strength of the wood must be preserved, and the drying slowed down until there is no injury to the mechanical properties of the wood, even though the appearance may be entirely satisfactory.

The conditions that will generally give satisfactory drying and preserve the strength of the wood are a temperature of from 110 to 140° F. or higher at the start, depending on the kind of wood and the thickness of the pieces, and a humidity of from 80 to 85. The temperature is gradually raised as drying proceeds to a final temperature of 135 to 160° F. or higher while the humidity is gradually lowered to around 30, depending on the thickness of the lumber and the degree of dryness required. The time required for drying depends on the thickness of the stock and the amount of moisture it contains. Some of the softer woods in the form of 1-inch boards may be dried in a few days to 10 per cent. moisture, while thick (3-inch) oak stock may require three months or more. The lumber should be inspected at frequent intervals during the run. If small checks appear, the humidity should be raised and probably the temperature lowered. A sample about 2 feet long may be cut from a typical piece in the stack to be dried before the run starts and its moisture and weight determined. This sample should then be replaced in the stack. By removing and weighing the sample during the run the rate at which drying is proceeding throughout the pile can be closely estimated. Sections cut from pieces in the stack at the completion of the run and resawed as in Figs. 64 and 65 may be used

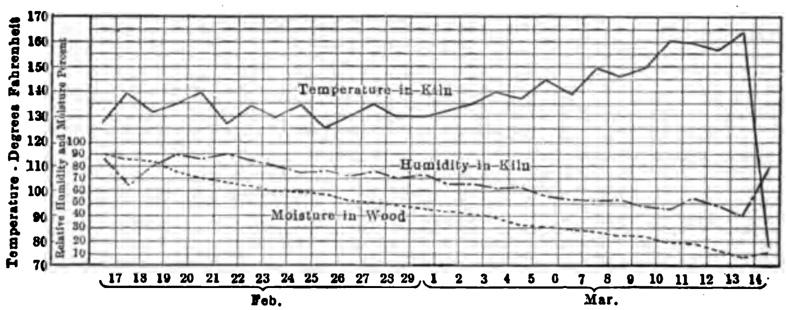


FIG. 99.—Typical conditions in a kiln during a run.

to show whether the lumber is casehardened or not, and also to show if the moisture is evenly distributed. Sections may also be cut into pieces and the moisture determined in the interior and surface portions to show the moisture distribution (see "Method of Determining Moisture in Wood" in Chapter III).

Figure 99 shows the conditions in a kiln during a run, with reference to temperature, humidity, and moisture in the wood. It will be noted that the humidity is kept high at first and lowered gradually. The temperature is held at a certain level for some time and then raised. The moisture is lowered gradually to a final condition of less than 10 per cent.

The maximum rate of drying at a given temperature is reached when moisture is evaporated from the surface of the wood just as fast as it is transmitted from the interior. This rate is fixed by the rate of transmission of moisture within the wood, and varies with different woods.

The temperature of drying apparently influences the rate of transmission of moisture within the wood. The higher the temperature of the wood the more rapid is the rate of transmission of the moisture, and hence the rate at which the moisture may be evaporated safely. This, of course, applies only to temperatures below those which might result in injury to the wood.

Figure 100 shows theoretical conditions in a kiln where both preliminary and final steaming are used. Casehardening that

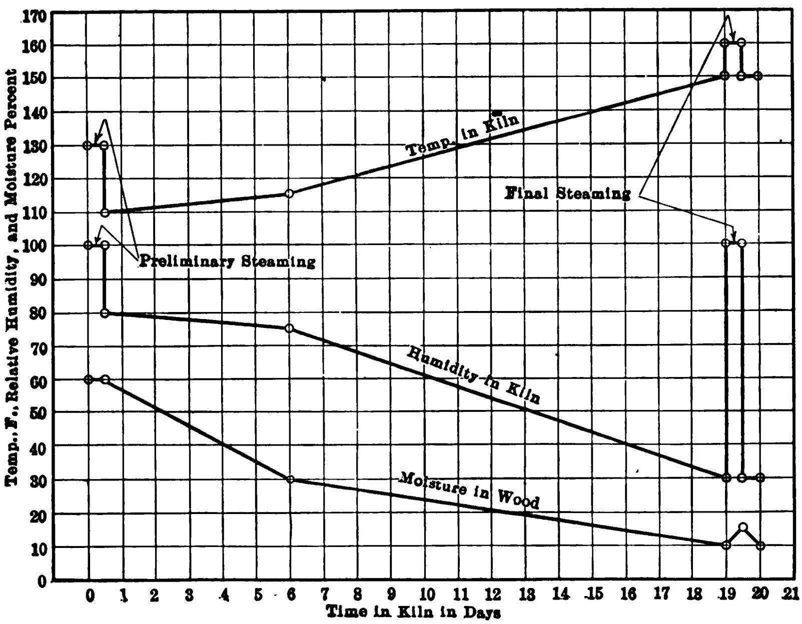


FIG. 100.—Theoretical conditions in kiln while drying lumber 2 inches thick of the *lighter* pines, spruces, etc.

occurs during the drying is removed by a few hours steaming at the end of the run. The oaks, hickories, and other heavier hardwoods require a longer period of drying to avoid checking and excessive casehardening. Lumber 1 inch thick can be dried in one-half the time given or less.

Drying tends to render wood more or less brittle. Although the strength of wood increases with its degree of dryness, yet wood which has been dried and resoaked is less resilient than when green. Therefore, where strength is the prime consideration, it is preferable not to dry the wood considerably beyond the degree at which it is to be used. The final stage of kiln drying is generally conducted at a humidity somewhat below the actual humidity that on long exposure would produce the same average moisture condition. This is done in order to hasten the drying and to make it uniform throughout each piece.

Storage of Dried Lumber.—Since wood is a very hygroscopic substance, lumber stored under certain conditions will tend to come to a moisture content corresponding to the temperature

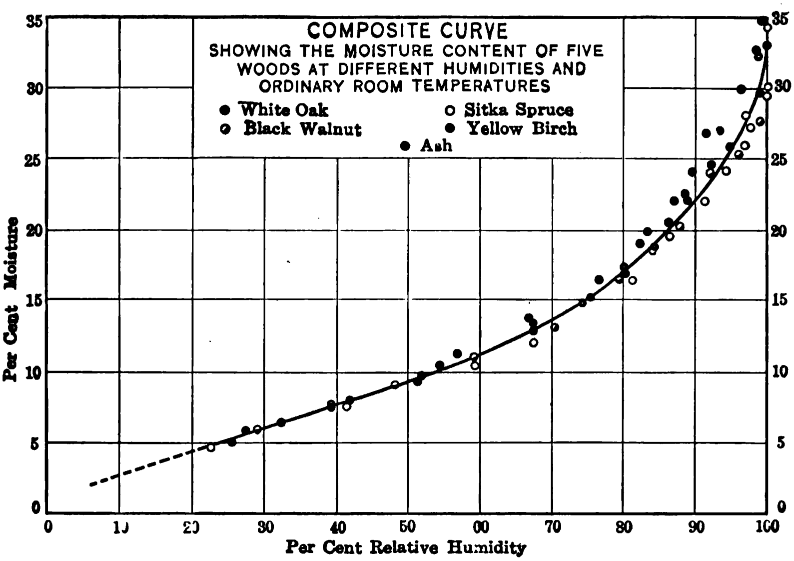


FIG. 101.—Composite curve of moisture content of five woods at different humidities and ordinary room temperature.

and humidity under which it is stored. Lumber kiln dried to a moisture content of 6 or 8 per cent. and then stored under an open shed will reabsorb moisture up to about 15 per cent., while lumber dried to 15 or 20 per cent. moisture and then stored in a wood-working shop will tend to dry out to about 6 per cent. The time required for lumber to reach a condition of moisture corresponding to the conditions of storage depends largely on the thickness of the material. The humidity of the storage conditions largely determines the final moisture. The moisture content reached by lumber stored under ordinary room temperatures for different degrees of humidity is shown in Fig. 101.

The data were obtained by storing samples of five different woods under different humidities until their weight was constant. There was no practical difference in the moisture content reached by the different woods at the same humidities. The proper humidities for storing lumber which it is desired to hold at a certain moisture content are shown by the curve. At higher temperatures the moisture content reached by the wood for any certain humidity would be less. For temperatures around 200° F. a humidity of about 80 would be required to hold wood at a moisture content of 10 per cent., while at room temperature (about 70° F.) a humidity of about 55 corresponds to 10 per cent. moisture.

CHAPTER VI

THE GRADING OF LUMBER BY MANUFACTURERS' ASSOCIATIONS[1]

PRINCIPLES OF LUMBER GRADING—MANUFACTURE AND DISTRIBUTION OF GRADED LUMBER—HARDWOOD LUMBER GRADING—HARDWOOD ASSOCIATIONS—COMPARISON OF RULES—SOFTWOOD LUMBER GRADING—GENERAL CHARACTER OF THE RULES FOR SOFTWOODS—DESCRIPTION OF TYPICAL RULES

PRINCIPLES OF LUMBER GRADING

The grade of a piece of lumber is at present determined by the number, size, and location of the visible defects it contains. Clear pieces are placed in the highest grade, pieces with a few defects in the next grade, and so on down to the lowest grades or culls.

Defects include knots, stained sap, shake, wane, rot, pitch pockets, splits, and seasoning checks. In lumber for some purposes the presence of certain defects is allowable; for other uses only clear material is suitable. Where only clear pieces are suitable the value of the raw material depends upon the number of such pieces of a certain size that can be obtained from it. In the case of sheathing for a house, over which the siding is nailed, knots, stained sap, and seasoning checks in reasonable quantity are allowed because they do not injure the lumber for that purpose. On the other hand, material for certain classes of furniture, table tops for example, must be clear and not less than a minimum width and length, so that the suitability of lumber for such use is entirely a matter of the clear cuttings that it will yield. Different uses call for cuttings of different kinds. Some products, such as flooring, require long, narrow cuttings for their manufacture; others, such as furniture stock, require short, wide cuttings. In some uses (highest grade flooring) one side only need be clear

[1] See paper by H. S. Betts and J. C. Nellis, Forest Service, Department of Agriculture.

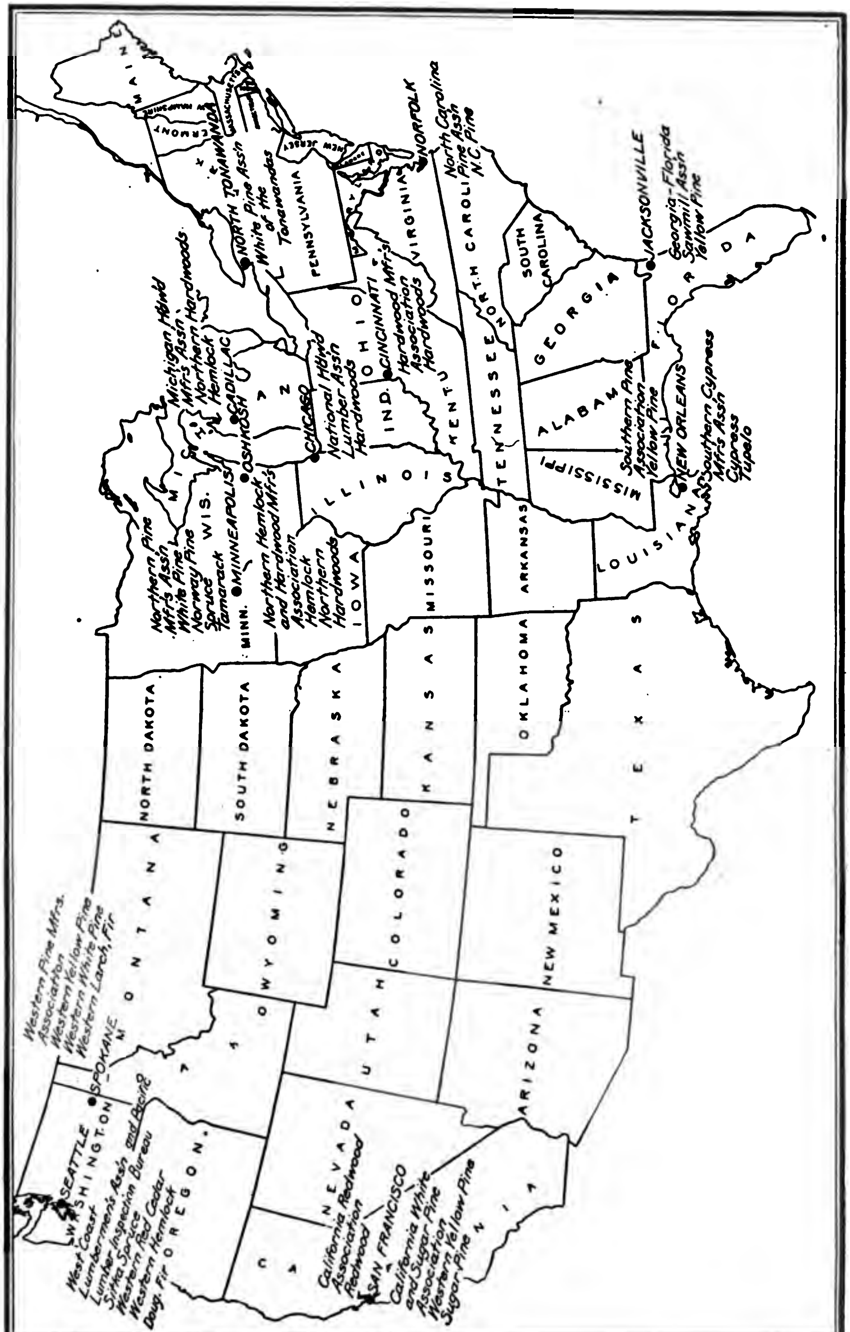


FIG. 102.—The principal lumber manufacturers' associations showing headquarters and woods covered by grading rules.

because the other does not show, while in other uses (best grade door stock) both sides of the cuttings are exposed to view, and should be clear. In certain uses, such as siding, one edge is covered when it is finally in place, so that some defects in the covered edge are allowable and the raw material is selected with this in mind.

Grading rules for lumber are generally prepared by associations of lumber manufacturers whose members cut certain species which grow in the same region. Figure 102 shows the names and headquarters of the principal lumber manufacturing associations and the woods covered by their grading rules.

MANUFACTURE AND DISTRIBUTION OF GRADED LUMBER

In the manufacture of graded material the trees are felled and the logs cut into standard lengths to a top diameter in the tree varying from 12 inches to 4 inches, depending on the species and on the condition of the market. When there is a large demand for low-grade material, as in prosperous times, it is possible to carry the utilization of the tree a good deal further than when the demand for low grades is very slack. This applies both to the smallness of top logs which can be used at a profit and to more or less defective logs which will not yield high-grade material. In some parts of the country logs are divided into two or three grades, depending on their size and the defects they contain. Log grading is generally based on the proportion of the higher grades of lumber that can be obtained from them.

The proportion of the different grades that are obtained from a log depends to a considerable extent upon the judgment and skill of the sawyer. This is probably true to a greater extent in hardwoods than in softwoods. There is more opportunity for the exercise of judgment in sawing the more valuable hardwoods than in sawing the conifers because in operations in conifers the logs are more regular and the methods more standardized.

In some parts of the country, especially New England, it is customary to manufacture what is known as "round edge" lumber. That is, the logs are simply sawed into flitches at a single setting, no attempt being made to trim the edges of the material. About 10 per cent. more lumber, board measure, is obtained by this method than by sawing all boards with parallel edges. Such lumber is usually loosely graded by local unwritten rules.

The distribution of lumber from the mills where it is manufactured is influenced largely by the grade of the material and its corresponding price. High-grade lumber can be shipped comparatively long distances and still yield a profit to the manufacturer in spite of a high freight charge. Low-grade material, however, of comparatively little value can stand only a short haul. On this account, it is generally only the higher and medium grades of species growing in different regions that come into competition. Woods put to special uses and structural timbers cut only in certain regions do not follow the general rule. The distribution of grades is also affected by the prosperity of the country. In good times the demand for the lower grades greatly increased, as a result of increased building and construction of all kinds; prices rise, and it is possible to ship low-grade material further and still make a profit on it. High-grade stock is much less influenced in both distribution and price by changes in business conditions.

HARDWOOD LUMBER GRADING

Hardwood Associations.—Nearly all hardwood lumber produced in North America is graded according to the rules of two lumber associations, the National Hardwood Lumber Association and the Hardwood Manufacturers' Association of the United States.

Fifty years ago practically no hardwood lumber was graded. There was only a very limited demand for it in the wood-using industries; the chief problem of manufacturers was finding a market, and they sold their output "mill run" to jobbers, wholesalers, and other buyers.

The first attempt to grade hardwood lumber on the market was made by an association of wholesale dealers in New York. The New York Lumber Association formulated rules for use in trading on the New York market and for export lumber. These rules, naturally, were extremely favorable to the jobber and wholesaler and admitted only entirely clear stock in the upper grades. Outside of New York there were no rules in force, until in 1894 the National Wholesale Lumber Association was organized to establish uniform grading rules for hardwoods. This association, by judicious revision of the old New York rules, succeeded in obtaining members representing both wholesalers and manufacturers. In 1900 the association changed its name to the National Hardwood Lumber Association. In the meantime the manufacturers of hardwood lumber in the Middle States had formed an organization of their own and adopted independent rules. This association was not successful and was finally merged with the National Harwood Lumber Association about 1900. Many of the manufacturers of the Middle States and especially in the South withdrew when the merger took place and organized the present Hardwood Manufacturers' Association of the United States.

There are other hardwood associations in existence at the present time, but they use the rules of one or the other above associations, having no separate rules of their own.

The members of the Hardwood Manufacturers' Association are manufacturers. They operate largely in the central and southern hardwood region.

The National Hardwood Lumber Association is the larger association, and is composed of manufacturers in the northern, central, and southern regions and wholesalers in all the principal distributing points.

The grades adopted by these two associations for the various kinds of hardwood lumber are shown in Table 21.

Table 21.—Grades Adopted for Hardwood Lumber Products

NATIONAL HARDWOOD LUMBER ASSOCIATION

August, 1917, Rules

Kinds of Woods Graded

Ash	Butternut	Hickory	Poplar
Basswood	Cherry	Locust	Red gum
Beech	Chestnut	Magnolia	Sycamore
Birch	Cottonwood	Mahogany	Tupelo
Black gum	Cypress	Maple	Walnut
Buckeye	Elm	Oak	Willow
	Hackberry	Pecan	

Oak, Plain-sawed, Red and White

Product	*Grades*
Lumber	Firsts & Seconds
	Selects
	No. 1, 2, 3 Common
	Sound Wormy

TABLE 21.—GRADES ADOPTED FOR HARDWOOD LUMBER PRODUCTS (*Contd.*)

Oak, Plain-sawed, Red and White (Continued)

Product	*Grades*
Squares	Firsts & Seconds
	Sound
	No. 1, 2 Common
Step Plank	Firsts & Seconds
	Common
Strips	Clear
	Clear Sap
	No. 1, 2 Common
Plank and Timbers	Common Dimension
	No. 1, 2 Bridge Plank
	Common Timbers
	Sound, Square-edged
Wagon Stock—	
Bolsters	No. 1, 2
Sandboards	No. 1, 2
Reaches	No. 1, 2
Poles	No. 1, 2
Sawed Felloes	No. 1, 2
Bending Oak	Firsts & Seconds
	No. 1 Common

Oak, Quarter-sawed, Red and White

Lumber	Firsts & Seconds
	Selects
	No. 1, 2, 3 Common
Strips	Clear
	Clear Sap
	No. 1, 2 Common

Hickory

Lumber	Firsts & Seconds
	No. 1, 2, 3 Common
Wagon Stock—	
Axles	No. 1, 2
Bolsters	No. 1, 2
Sandboards	No. 1, 2
Reaches	No. 1, 2
Eveners	No. 1, 2

Poplar

Lumber	Panel & Wide No. 1
	Firsts & Seconds
	Saps
	Selects
	Stained Saps
	No. 1, 2 (A & B), 3 Common

TABLE 21.—GRADES ADOPTED FOR HARDWOOD LUMBER PRODUCTS (*Contd.*)

Poplar (Continued)

Product	*Grades*
Squares	Firsts & Seconds Sound No. 1, 2 Common
Strips	Clear Sap No. 1, 2 Common
Lath	No. 1, 2
Wagon Box Boards	One Grade
Bevel and Drop Siding	No. 1, Selects No. 1, 2 Common
Dressed Dimension Strips	No. 1, Selects No. 1, 2 Common
Casing and Base	Firsts & Seconds Selects No. 1 Common
Flooring, Partition, and Ceiling	No. 1, Selects No. 1, 2 Common
Moldings	No. 1, 2

Poplar, Quarter-sawed

Lumber	Firsts & Seconds No. 1 Commons

HARDWOOD MANUFACTURERS' ASSOCIATION OF THE UNITED STATES

March 1, 1917, Rules

Kinds of Woods Graded

Ash	Buckeye	Hackberry	Pecan
Basswood	Butternut	Hickory	Poplar
Beech	Cherry	Magnolia	Red gum
Birch	Chestnut	Mahogany	Sycamore
Black gum	Cottonwood	Maple	Walnut
	Elm	Oak	

Oak, Plain-sawed, Red or White

Product	*Grades*
Lumber	Firsts & Seconds (FAS) Selects No. 1, 2, 3, 4 Common Firsts & Seconds Wormy No. 1 Common Wormy Core Stock
Strips	Clear Face No. 1, 2 Common

TABLE 21.—GRADES ADOPTED FOR HARDWOOD LUMBER PRODUCTS (*Contd.*)

Oak, Plain-sawed, Red or White (Continued)

Product	*Grades*
Step Plank	Firsts & Seconds (FAS) No. 1 Common
Plank and Timbers—	
Construction Timbers and Plank	Construction Oak Structural Timbers Sound, Square Edge
Locomotive and Car Timbers	
Switch and Cross Ties	
Bridge and Crossing Plank	
Sheet Piling	
Cattle Guards	
Bumping Posts	
Wagon Stock—	
Bolsters	One Grade
Sandboards	One Grade
Reaches	One Grade
Poles	One Grade
Sawed Felloes	One Grade
Bent Rims	One Grade
Wagon Spokes (White Oak)	Second Growth, A. B.
Dimension Material—	
Seat Stock	One Grade
Chair Frame Stock	One Grade
Table Tops	One Grade
Chair Backs	One Grade
Band-sawed Patterns	One Grade
Implement Stock—	
Plow Handle Strips	One Grade

Oak, Quarter-sawed, Red or White

Lumber	Firsts & Seconds (FAS) Selects No. 1, 2, 3, 4 Common
Strips	Clear Face No. 1, 2 Common
Step Plank	Firsts & Seconds (FAS) No. 1, Common

Hickory

Lumber	Firsts & Seconds (FAS) No. 1, 2, 3, 4 Common
Wagon Stock—	
Vehicle Wheel Stock	A, B, C, D, E
Axles	No. 1
Bolsters	One Grade

TABLE 21.—GRADES ADOPTED FOR HARDWOOD LUMBER PRODUCTS (*Contd.*)

Hickory (Continued)

Product	*Grades*
Wagon Stock (*Continued*)	
Sandboards	One Grade
Reaches	One Grade
Eveners	One Grade
Poplar	
Lumber	Panel & Wide No. 1
	Firsts & Seconds (FAS)
	Selects
	Saps
	Wide No. 2
	No. 1, 2, 3, 4 Common
	Scoots
Car Sign Boards	One Grade
Wagon Box Boards	One Grade
Shorts	No. 1, 2
Strips	No. 1, Select
	No. 1, 2 Common
Squares	Firsts & Seconds (FAS)
	No. 1, Common
Bevel and Drop Siding	No. 1, Selects
	No. 1, 2 Common
Dressed Dimension Strips	No. 1 Selects
	No. 1, 2 Common
Casing and Base	Firsts & Seconds
	Saps and Selects
	No. 1 Common
Flooring, Partition, and Ceiling	No. 1, Selects
	No. 1, 2 Common
Moldings	No. 1, 2
Poplar, Quartered	
Lumber	Firsts & Seconds (FAS)
	No. 1, 2 Common

NOTE.—Products and grades for oak, hickory, and poplar only are given in Table 21. Products and grades for other woods listed are similar.

Comparison of the Rules.—The first rules for grading hardwoods adopted by the New York Lumber Association contained only a few grades applicable to all species and were comparatively crude and unsatisfactory. The present rules of the Hardwood Manufacturers' Association contain about 300 grades, including rules for the inspection of all kinds of hardwood lumber and special forms, such as molding, partition, siding, flooring, etc. The rules now used by the National Hardwood

Lumber Association contain about 400 grades, including all species and special forms.

The comparative merit of the grading rules of the two associations has been a mooted question for a number of years. Numerous attempts have been made to bring about an agreement between the rival associations. Each association has tried to convince the other of the superiority of its rules and to persuade the other to adopt them; and efforts have been made to bring about the adoption, on common, of a single set of rules. Every effort has failed, in spite of the fact that the members of both associations desire uniformity in grading hardwoods. The American Hardwood Manufacturers' Association, recently organized to exploit hardwoods, is expected to be a strong factor in the movement to effect uniformity in rules.

A comparison of the wording of the two rules seems to show that they are very similar. The chief difference is whether the grading is to be based upon the better side of the piece, the poorer side, or both sides. The National Hardwood Lumber Association rules formerly required inspection to be made on the poorer side of the piece; but now one regular and two special grades out of a total of seven are inspected on the face or best side. The Hardwood Manufacturers' Association requires both sides of the piece to be considered in determining the grade. The difference between inspection on the worse side and on both sides affects the whole of each rule so that the similarity of wording in other respects is misleading. It is obvious that inspection on the worse side is more satisfactory to the jobbers, and inspection on both sides to the manufacturers.

Another difference is in the number of grades. The National rules include Firsts and Seconds, Selects, and Nos. 1, 2, and 3 Common, as well as special Nos. 1 and 2 Common Face; while the Manufacturers' rules provide for Firsts and Seconds and Nos. 1, 2, 3, and 4 Common, also Selects in oak and poplar.

The following summary of the rules of both associations is an attempt to pick out the fundamental requirements for the different grades, irrespective of species. It is, therefore, not to be considered as a grading rule for hardwoods, but is merely a brief, general summary of the principles involved, without regard to the innumerable details of exact inspection of specific kinds of woods.

Summary of the Rules of the National Hardwood Lumber Association

Note.—Inspection must be made upon the poorer side of the piece, except as otherwise specified.

1. Standard Lengths.

Standard lengths are from 4 to 16 feet inclusive in 1 foot multiples, but not over 15 per cent. of odd lengths are admitted.

2. Standard Thicknesses for Rough Lumber.

1/4 in.	5/8 in.	1 1/4 in	2 in.	3 1/2 in.	5 in.
3/8 in.	3/4 in.	1 1/2 in.	2 1/2 in.	4 in.	5 1/2 in.
1/2 in.	1 in.	1 3/4 in.	3 in.	4 1/2 in.	6 in.

The standard thicknesses of lumber surfaced on two sides are 3/16 in. less for pieces 1 in. and under, 5/32 in. less for pieces 1 1/4 in. and 1 1/2 in., and 1/4 in. less for pieces 1 3/4 in. and over. Surfaced lumber is measured on the basis of rough dimensions.

3. (*a*) Standard Grades.

Firsts and Seconds	No. 2 Common
Selects	No. 3 Common
No. 1 Common	

(*b*) **Special Grades.**

No. 1 Common Face	No. 2 Common Face

4. Woods Included.

Ash	Cottonwood	Pecan
Basswood	Cypress	Poplar
Beech	Elm	Red gum
Birch	Hackberry	Sycamore
Black gum	Hickory	Tupelo
Buckeye	Locust	Walnut
Butternut	Magnolia	Willow
Cherry	Maple	
Chestnut	Oak	

5. Description of Standard Grades.

Grade	*Length Allowed*	*Width Allowed*	*Defects Allowed*
Firsts and Seconds	8 to 16 feet (Not more than 20% to be less than 12 feet)	6 in. and wider	Ranging from no defects in pieces 2 to 9 surface ft. to 5 defects in pieces of 20 surface feet.

Grade	*Length Allowed*	*Width Allowed*	*Defects Allowed*
Selects	6 to 16 feet (Not more than 30% to be less than 12 feet)	4 in. and wider	Ranging from pieces 6 ft. and 7 ft. long, clear one face, to larger pieces not less than Firsts and Seconds on best face and No. 1 Common on reverse.
No. 1 Common	4 to 16 feet (Not more than 10% to be less than 8 feet)	3 in. and wider	Must be clear in 4 ft. and 5 ft. lengths, and in 3 in. and 4 in. widths under 8 ft. long. Wider and longer pieces must work 66⅔% clear on from 2 to 4 cuttings. (No cutting less than 4 in. × 2 ft. or 3 in. × 3 ft.)
No. 2 Common	4 to 16 feet (Not more than 10% under 6 feet)	3 in. and wider	Must work 50% clear face in from 3 to 5 cuttings according to width and size of piece. No cutting less than 3 in. × 2 ft. (In some woods cuttings required sound instead of clear.)
No. 3 Common	4 to 16 feet	3 in. and wider	Must work 25% sound cuttings. (No cutting less than 1½ in. wide nor less than 36 square inches.)

Exceptions.—Firsts and Seconds for rock elm, hickory, and pecan are as follows:

Grade	*Length Allowed*	*Width Allowed*	*Defects Allowed*
Firsts and Seconds	8 to 16 feet (30% of 8 ft. to 10 ft. lengths are allowed)	4 in. and wider	Ranging from clear pieces 4 in. wide to pieces with 4 defects in 18 surface feet.

Firsts and Seconds for walnut and butternut are as follows:

Firsts and Seconds	8 to 16 feet (Not more than 35% to be less than 10 feet)	6 in. and wider	Ranging from 1 standard defect and ¾ in. sap in pieces under 10 ft. long and under 8 in. wide to 3 defects and 3 in. of sap in pieces 10 ft. long and over by 12 in. wide and over.

6. Description of Special Grades.

No. 1 Common Face grade is the same as Standard No. 1 Common, except that it is inspected from the better side.

No. 2 Common Face grade is the same as Standard No. 2 Common except that it is inspected from the better side.

Panel and Wide No. 1

(When combined must be at least 50% Panel)

POPLAR, COTTONWOOD, AND GUM

Grade	*Width and Thickness*	*Lengths*	*Defects Allowed*
Panel	18 in. and over by ⅜ in. to 2 in.	8 to 16 feet	50% of total quantity must be clear both sides; remainder may contain defects, provided 90% of the piece can be used for panels in cuttings 4 ft. long by the full width.

Grade	*Width and Thickness*	*Lengths*	*Defects Allowed*
Wide No. 1	18 in. and over by 3/8 in. to 2 in.	6 to 16 feet	6 ft. and 7 ft. pieces must be clear; longer pieces must work 75% clear in 4 ft. and longer cuttings by full width of piece.

7. Standard Defects.

Each of the following defines one standard defect:

(1) One knot 1¼ in. in diameter.

(2) Two knots not exceeding in extent of damage one 1¼ in. knot.

(3) One split not diverging more than 1 inch to a foot, and not longer in inches than the surface measure of the piece in feet.

(4) Worm, grub, knot, and rafting pin holes not exceeding in extent of damage one 1¼ in. knot.

SUMMARY OF THE RULES OF THE HARDWOOD MANUFACTURERS' ASSOCIATION OF THE UNITED STATES

NOTE.—Both sides of the piece must be taken into consideration in making the grade.

1. Standard Lengths.

Standard lengths are from 4 to 20 feet; 15 per cent. of odd lengths are admitted in any grade.

2. Standard Thicknesses for Rough Lumber.

3/8 in.	1 in.	2 in.	3 in.
½ in.	1¼ in.	2¼ in.	3¼ in.
5/8 in.	1½ in.	2½ in.	3½ in.
¾ in.	1¾ in.	2¾ in.	4 in.

Ten per cent. of the shipment may be 1/16 in. scant.

The standard thicknesses of lumber surfaced on two sides is 3/16 in. less than the thickness of the rough lumber for pieces from ½ in. to to 1 in., 5/32 in. less for pieces 3/8 in., 1¼ in., and 1½ in., and ¼ in. less for pieces 1¾ in. and over. Surfaced lumber is measured on the basis of rough dimensions.

3. Names of Standard Grades.

Firsts and Seconds	No. 3 Common
No. 1 Common	No. 4 Common
No. 2 Common	

7. Standard Defects.

Each of the following is a standard defect:

1. One knot $1\frac{1}{4}$ inches in diameter.
2. Two knots so located that the damage is not more than for one standard knot.
3. Worm holes, grub holes, or rafting pin holes not exceeding in damage one standard knot.
4. Heart, shake, rot, dote, or any other defects not exceeding in damage one standard knot.
5. Bark or waney edge not more than 1 inch in average width and not extending more than one-third the length of the board. Must show on one side only.

SOFTWOOD LUMBER GRADING

General Character of the Rules for Softwoods

The grading of softwood lumber is complicated by the large number of rules in use. Different kinds of wood, such as southern yellow pine, white pine, Douglas fir, etc., are graded under different rules. Some species are included under the rules of two different lumber associations. The grades adopted for the various kinds of softwood lumber by the principal lumber associations throughout the United States are shown in Table 22.

Table 22.—Grades Adopted for Softwood Lumber Products by Principal Lumber Associations

Southern Pine Association

1917 Rules for Yellow Pine (Longleaf, Loblolly, and Shortleaf Pine)

Product	*Grade*
Finishing	A, B, C
	Panel Shop
Flooring	Flat Grain—A, B, C, D,
	No. 1, 2, 3 Common
	Edge Grain—A, B, C, D,
	No. 1 Common
	No. 1 Common Factory
Ceiling	A, B
	No. 1 & 2 Common
Wagon Bottoms	A & B
Drop Siding	A & B
	No. 1 & 2 Common
Bevel Siding	A & B
	No. 1 & 2 Common

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
Partition	A & B
	No. 1 & 2 Common
Molded Casing, Window, and Door Jambs	A, B & C
Molding	B & Better
Common Boards, Shiplap, and Barn Siding	No. 1, 2, 3, 4 Common
Grooved Roofing	No. 1 Common
Fencin	No. 1, 2, 3, 4
Dimension and Heavy Joist	No. 1, 2, 3 Common
Lath	No. 1 & 2
Timbers	Select Structural
	Merchantable
	Square Edge & Sound
	No. 1 Common

Georgia-Florida Sawmill Association

1916 Rules for Lumber and Planing-mill Products

(Same as Southern Pine Association Rules)

Interstate Rules of 1905[1] *and* 1916[2]

Yellow Pine

Product	*Grade*
Flooring Boards Planks Scantling Dimension Stepping Rough Edge or Flitch	Prime Merchantable Standard

North Carolina Pine Association

1917 Rules for Kiln-dried North Carolina Pine (Loblolly and Shortleaf Pine)

Product	*Grade*
Rough and Dressed Lumber	No. 1, 2, 3, Box, Culls
	Merchantable Red Heart
	Cull Red Heart
	No. 1 & 2 Shop
	No. 1 & 2 Bark Strips
	Box Bark Strips
Flooring	No. 1, 2, 3 & 4 Flat Grain
	No. 1 & 2 Rift

[1] Adopted by Georgia-Florida Sawmill Association, North Carolina Pine Association.

[2] Adopted by Georgia-Florida Sawmill Association.

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
Ceiling	No. 1, 2, 3 & 4
Partition	No. 1, 2, 3 & 4
Fencing	No. 1, 2, 3 & 4
Base and Casing	No. 1 & 2
German, Bevel and Drop Siding	No. 1, 2, 3 & 4
Rails	No. 1 & 2
Molding	No. 1
Factory Flooring and Roofers	Same as Box
Plank, Dimension and Timber	One Grade

Grades for air-dried are No. 1, 2, 3, Box, Culls, and Framing.

Northern Pine Manufacturers' Association

1915 Rules for Northern White Pine, Spruce, and Tamarack

Product	*Grade*
Thick Finishing	1st, 2d, 3d Clear
	A, B, C, D Select
Inch Finishing	1st, 2d, 3d Clear
	A, B, C, D Select
	D Stock & Box
Siding	A & Clear
	B, C, D & E
Flooring	A, B, C, D Flooring
	Farmers Clear Flooring
	No. 1, 2, 3 Fencing (D & M)
Shiplap, Grooved, Roofing, and D & M	No. 1, 2 & 3
Factory Lumber	No. 1, 2, 3 Shop Common
	Inch Shop Common
	Short Box
	Factory A Select & Better
	Factory B & C Select
Thick Common Lumber	Tank Stock
	Select Common
	No. 1, 2, 3, 4, 5 Common
Common Boards and Strips	No. 1, 2, 3, 4, 5 Common
Dimension	No. 1, 2, 3
Lath	No. 1 & 2
Fencing	No. 1, 2, 3, 4

White Pine Association of the Tonawandas

Rules for White Pine—Not Dated

Product	*Grade*
	Uppers
	Selects

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
	Fine Common
	No. 1, 2 & 3 Cuts
	No. 1 & 2 Moldings
	Stained Saps
	Star Clear
	No. 1 Shelving & Dressing
	No. 2 Dressing
	No. 1 & 2 Shelving
	No. 1, 2 & 3 Barn
	No. 1 Box
Bevel Siding	
Moldings	
Lattice	
Pickets	

Southern Cypress Manufacturers' Association

1917 Rules for Cypress

Product	*Grade*
Tank Stock	One Grade
Finishing	A, B, C
Factory Lumber	Factory Selects
	Shop
Boards	Select Common
	Heart Select Common
	No. 1 & 2 Common
	Box, Peck
Siding, Flooring, Ceiling	A, B, C & D
Shiplap, Casing, Base	A, B, C & D
Grooved Roofing, Partition	A, B, C & D
Switch Ties	One Grade
Cross Ties	Standard No. 1 Peck
Short Lumber	B & Better
Window and Door Frames, Jambs, Etc	B & Better
Panel Stock	B & Better
Pickets	No. 1 & 2
Battens and Squares	One Grade
Car Roofing and Siding	C & Better
Car Lining	One Grade

National Hardwood Lumber Association

1917 Rules for Cypress

Product	*Grade*
Tank	One Grade
Finishing	Firsts & Seconds
	Selects

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
Factory Lumber	No. 1 & 2 Shop
Boards	No. 1 & 2 Commons
	No. 1 & 2 Boxing
	Peck
Finished Cypress	A, B, C, & D Finish
Panel	B & Better
Siding and Flooring	A, B, C & D
Ceiling and Partition	A, B, C & D
Car Roofing and Siding	C & Better
Car Lining	One Grade
Battens and Squares	One Grade
Pickets and Lath	No. 1 & 2

West Coast Lumbermen's Association

1917 Rail Rules for Douglas Fir,[1] Sitka Spruce, Western Red Cedar, and Western Hemlock

Product	*Grade*
Flooring	No. 1, 2, 3, 4 Clear Edge
	No. 2 & Better, 3, 4 Clear Flat Grain
Ceiling, Partition, Drop Siding, and Rustic	No. 2 Clear & Better
	No. 3 & No. 4 Clear
Bungalow or Colonial Siding	No. 2 Clear & Better Resawn
Bevel Siding	No. 2 Clear & Better
	No. 3 Clear
Finish, Casing, and Base	Selected Flat Grain
	No. 2 Clear & Better
	No. 3 Clear
Boards and Shiplap	Inch Select Common
	No. 1, 2, 3 Common
Dimension, Plank, and Small Timbers	Selected Common
	No. 1 & 2 Common
Timbers	Selected Common
	No. 1 & 2 Common
Factory Lumber	Factory Select & Better
	No. 1, 2 Shop Common
	Inch Shop Common
	Panel Lumber
Stepping	No. 2 Clear & Better
	No. 3 Clear
Tank Stock	One Grade.
Windmill Stock	Selected Common

[1] Products and grades are given for Douglas fir only. Those for the other species listed differ.

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
Silo Stock	No. 2 Clear & Better
	Selected Common
Well Tubing	No. 3 Clear & Better
Corn Cribbing	No. 3 Clear & Better
	Selected Common
Pickets	One Grade
Battens	One Grade
Mining Timber	No. 1
Well Curbing	Selected Common
	No. 1 Common
Wagon Bottoms	No. 2 Clear & Better
Lath	One Grade
Turned Porch Columns	No. 1
Ship Decking	One Grade
Turning Squares	No. 2 Clear & Better
Pipe Staves	One Grade

Pacific Lumber Inspection Bureau

1917 Domestic Rules for Douglas Fir,[1] Western Hemlock, Sitka Spruce, Western Red Cedar, and Port Orford Cedar

Product	*Grade*
Rough Clears	No. 2 Clear & Better
	No. 3 Clear
Finish, Casing & Base	Selected Flat Grain
	No. 2 Clear & Better
	No. 3 Clear
Boards and Shiplap	Inch Selected Common
	No. 1, 2 & 3 Common
Dimension, Plank, and Small Timbers	Selected Common
	No. 1, 2, 3 Common
Timbers	Selected Common
	No. 1 & 2 Common
Factory Lumber	Factory Select & Better
	No. 1 & 2 Shop Common
	Inch Shop Common
	Panel Lumber
Flooring	No. 1, 2, 3, 4 Clear Edge Grain
	No. 2 Clear & Better, 3, 4 Clear Flat Grain
Stepping	No. 2 Clear & Better
	No. 3 Clear

[1] Products and grades are given for Douglas fir only. Those for the other species listed differ.

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
Rustic Drop Siding Ceiling and Partition	No. 2 Clear & Better No. 3, 4 Clear
Bungalow or Colonial Siding	No. 2 Clear & Better Resawn
Tank Stock	One Grade
Cross Arm Stock	One Grade
Silo Stock	No. 2 Clear & Better Selected Common
Pipe Stave Stock	One Grade
Ship Plank	One Grade
Ship Decking	One Grade
Mining Timber	One Grade
Railroad Ties	No. 1 & 2
Car Stakes	One Grade
Pickets	No. 1 & 2
Lath	One Grade

Pacific Lumber Inspection Bureau

1917 Export Rules for Douglas Fir,[1] Western Hemlock, and Sitka Spruce

Product	*Grade*
Rough Clears	No. 2 Clear & Better
Boards, Dimension, and Timbers	Merchantable Common
Flooring	No. 1, 2, 3 Clear Edge Grain No. 2 Clear & Better & 3 Clear Flat Grain
Ceiling and Rustic Siding	No. 2 Clear & Better
Stepping	No. 2 Clear & Better
Mining Timber	One Grade
Railroad Ties	One Grade
Ship Plank	One Grade
Deck Plank	One Grade
Pipe Stock	One Grade
Pickets	One Grade
Staves	No. 1 & 2
Lath	One Grade

[1] Products and grades are given for Douglas fir only. Those for the other species listed differ.

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Western Pine Manufacturers' Association

1917 Rules for Western White Pine,[1] Idaho White Pine,[2] Engelmann Spruce, White Fir, Western Red Cedar, Douglas Fir, and Larch

Product	*Grade*
Finishing	B Select & Better
	C & D Select
Siding	B & Better
	C, D & E
Common Lumber	No. 1, 2, 3, 4 & 5 Common Board and Strips
Lath	No. 1 Pine Lath
	No. 1 Mixed Lath
	No. 2 Lath
Tank Stock	One Grade
Factory Lumber	No. 1, 2 & 3 Shop Common
	Factory C Select & Better
	Inch Shop Common
	Short Box
Dimension and Timbers	No. 1
Cribbing	One Grade
Shiplap	
Drop Siding	
Beveled Siding	
Ceiling	
Grooved Roofing	
Flooring	

California White & Sugar Pine Manufacturers' Association

1916 Rules for Sugar Pine and California White Pine (Western Yellow Pine)

Product	*Grade*
Finishing	No. 1 & 2 Clear (or B Select & Better)
	C Select
	D Select
Siding, Bevel	B & Better
	C & D
Flooring and Ceiling, Drop Siding	B & Better
	C & D
	No. 1, 2 & 3 Fencing

[1] *Pinus ponderosa,* U. S. Forest Service name—Western Yellow Pine.
[2] *Pinus monticola,* U. S. Forest Service name—Western White Pine.

TABLE 22.—GRADES ADOPTED FOR SOFTWOOD LUMBER PRODUCTS BY PRINCIPAL LUMBER ASSOCIATIONS—(*Continued*)

Product	*Grade*
Factory Plank	No. 3 Clear (or Factory C Select or No. 1 Cuts)
	No. 1, 2 & 3 Shop
	Inch No. 3 Clear
	Inch Shop
Thick Common	Select Common
Boards and Fencing	No. 1, 2, 3 & 4 Common
Shiplap, Grooved Roofing, Drop Siding and D & M	No. 1, 2 & 3 Common
Lath	No. 1 & 2

California Redwood Association

1917 Rules for Redwood

Product	*Grade*
Uppers	Clear
	Sap Clear
	Select
	Standard
Sundry Commons	Extra Merchantable
	Merchantable
	Construction
	Shop Common
	Inch Shop Common
	Subflooring and Sheathing Stock
Channel Rustic	
V Rustic	
Drop Siding	
Bevel Siding	
Battens	
Shiplap	
Pickets	

Northern Hemlock & Hardwood Manufacturers' Association
1913 Rules for Hemlock

Product	*Grade*
Boards and Strips	Thick D & Better
	Inch Clear & Select
	Inch D Stock
	No. 1, 2, 3, 4 Common
Piece Stuff or Dimension	No. 1, 2, 3, 4 Dimension
Lath	No. 1 & 2
Flooring	
Ceiling	
Shiplap	
Drop Siding	

The various mills originally made their own rules to suit their special conditions. This might have been satisfactory where a mill supplied practically all the lumber used in its vicinity; but as soon as mills with different rules for the same timber began to sell in the same territory there was bound to be confusion and dissatisfaction. As means of transportation grew easier and cheaper and lumber was shipped greater distances from its source, organizations of manufacturers and dealers in different regions drew up rules to enable them to handle lumber in standard sizes and with less misunderstanding as to quality. By the use of such rules, manufacturers could tell more satisfactorily the quality of lumber wanted by dealers, and the dealers in turn could be surer that their orders would be correctly filled. These rules first classified the various kinds of lumber products, such as siding, boards, ceiling, flooring, finishing, dimension, etc., and then specified the size and number of defects, such as knots and checks, allowed in the various grades of each product. At first the rules were comparatively simple; but they have been expanded and new ones added to cover special products and the rules for each product further subdivided until pamphlets of 50 printed pages may be required to describe the different grades, sizes, and shapes of the various standard lumber products of one kind of wood.

The most common defects specified in softwood grading rules are knots, stained sap, shake, wane, rot, pitch, splits, and seasoning checks. Inspection is usually specified on the better or dressed side. However, factory lumber used for the manufacture of doors, sash, etc., which must show on both sides, is graded from the poorer side. There is a tendency to avoid definite detailed specifications for the different grades, especially in certain of the white pine grading rules, in which only a general description of each grade and numerous examples of pieces that should be admitted are given. In such cases, the grade of each piece may be left largely to the judgment of the inspector.

Standard lengths and widths of softwoods differ somewhat under the various rules and also under different classes of material and grades in the same rules. In some sets of rules standard sizes are not listed completely.

The various lumber products to which grades are given by the different lumber associations generally include finish, flooring, siding, ceiling, boards, timbers, fencing, etc. The methods used by various associations for describing the grades differ widely. In some rules the letters A, B, C, and D are used to designate grades of material for finish, ceiling, flooring, etc., and the numbers 1, 2, 3, and 4, usually with the term "common," are used for grades of common lumber, boards, dimension, etc. Other rules designate their highest grades of finish as 1, 2, and 3 Clear, either with or without lower grades of finish material designated A, B, C, and D.

Description of Typical Rules for Softwoods

Following is a description of the grading rules of a few of the most important species.

SOUTHERN YELLOW PINE

Southern yellow pine includes longleaf, shortleaf, loblolly, and associated species of minor importance, such as slash and pond pine. The grading rules in common use are as follows:

1. Interstate Rules of 1905 and 1916, used principally in the southeastern United States and in Atlantic Coast markets.
2. Southern Pine Association Rules, used largely by Gulf State manufacturers for inland trade.
3. North Carolina Pine Association rules, used on the Atlantic Coast.
4. Gulf Coast Classification, used in export trade.

Interstate Rules.—The Interstate rules of 1905 and 1916, which are used by the Georgia-Florida Sawmill Association for dimension and timbers, by the North Carolina Pine Association, and by lumber trade associations of the Atlantic Coast, are characterized principally by their simplicity. They are divided into three parts: General Rules, Classification, and Inspection. Seven classes of lumber are given: flooring, boards, plank, scantling, dimension, stepping, and rough edge or flitch; and the sizes are specified under each class. Under Inspection three grades are given: standard, merchantable, and prime. Prime is the highest grade. These grades are based on the number and position of defects and the amount of heart. The 1916 rules differ from the 1905 rules in that they contain a density requirement.

Southern Pine Association Rules.—The Southern Pine Association rules for grades of yellow pine lumber are a revision of the old Yellow Pine Manufacturers' Association rules. Separate rules are issued for (1) lumber and dimension, (2) timbers, (3) car material, and (4) bridge and trestle timbers. A large number of different classes of products are given, such as finishing, flooring, ceiling, common boards, dimension, etc. The grades are defined under each of these classes. The letters A and B are used to designate the higher grades for finish and planing-mill products, and the Nos. 1, 2, and 3, with the term "common," are used for lower grades of planing-mill products, common boards, and dimension. Figure 103 shows boards of three grades. The requirements of each grade are not the same in the different classes of products; they vary with the sizes and requirements

Fig. 103.—Boards of three grades—Southern Pine Association.

of each class. In general, the material is graded from the face or better side.

Grade A is practically free from defects on one side except in the greater widths. Grade B allows a few minor defects, such as splits, small knots, and pitch pockets. The Common grades allow larger defects and a greater number of them than A and B. No. 1 Common in general allows sound knots not over a certain diameter or smaller defects which do not impair its use; No. 2 Common allows knots not necessarily sound, not more than a certain specified diameter, and other defects if not too large; No. 3 Common allows coarse knots, knot holes, and other defects, if they are not so injurious as to prevent the use of the lumber; No. 4 Common is "defective lumber."

The Georgia-Florida Sawmill Association has reprinted the Southern Pine Association rules for lumber and planing-mill products in its rule book and now uses them for these items in place of the Interstate rules.

The Southern Pine Association rules for timbers include the "density" rule prepared for structural material by the Forest Service. This rule requires a proportion of one-third summerwood (the hard, dark colored parts of the annual ring) in the cross section and disregards botanical distinction. The grades given are No. 1 Common, Square Edge and Sound, Merchantable, and Select Structural Material, which is the highest grade. The first three of these grades may or may not include the density rule, the term "dense" being used to specify material conforming to the density rule and "sound" to include material without the density rule requirement. No. 1 Common Timbers are not required to conform to the General Timber Specifications, which exclude injurious shakes and unsound knots; but there are restrictions on the amount of wane and size of knots for different sizes of material. Square Edge and Sound Timbers must be free from wane. Merchantable Timber must have approximately two-thirds heart on the wide faces. The "Select Structural" grade conforms to the Density Rule and also has restrictions, recommended by the Forest Service, as to knots, shakes, checks, and cross grain. Wane is not permitted in this grade. There must be at least 85 per cent. heart measured around the girth anywhere in the length.

North Carolina Pine Association Rules.—The grading rules for kiln-dried North Carolina pine adopted by the North Carolina Pine Association apply to lumber from 1 to 2 inches in thickness. The principal grades are Nos. 1, 2, 3, and 4 (or Box). No. 1 must be practically clear of defects up to 8 inches in width, except a limited amount of pitch streak; No. 2 grade allows a limited number of small sound knots and other small defects; No. 3 allows larger tight knots; and No. 4, or Box, contains large, reasonably sound knots and other smaller defects. There are also several minor grades which are largely cull and from which merchantable lumber can be cut with a specified maximum per cent. of waste.

The grading rules for air-dried North Carolina pine are the same as for kiln dried except that 25 per cent. sap stain is allowed for No. 2, 50 per cent. for No. 3, 75 per cent. for No. 4, and 100 per cent. for Culls.

The Shortleaf Pine Plank and Dimension Rules consist of a set of brief general rules defining a single grade for each of these classes of material. They are the official rules of the North Carolina Pine Association and a number of lumber trade associations on the Atlantic Coast.

Gulf Coast Classification.—The Gulf Coast Classification of resawn lumber and sawn timber was first issued by the old Gulf Coast Lumber Exporters' Association and adopted in 1915 by the Southern Pine Association for export trade. Under "Resawn Lumber" the different kinds of lumber are classified as flooring, boards and planks, deals, scantling, dimension, kiln-dried saps, and air-dried saps. Under each class the sizes are given and the grades, which are for the most part as follows: Special or Crown, Extra or French Prime, Prime, Standard or Genoa Prime, Merchantable, and Square Edge. The grades differ as to amount of heart and defects specified, and the same grade differs to a greater or less degree in its requirements in the different classes of material. Two other brief sets of rules are given, "Usual South American or Standard River Plate" and "West Indian." Under "Sawn Timber" are brief rules adapted for use with this class of material. All these rules have high heart specifications in comparison to rules used in domestic trade.

WHITE PINE—EASTERN OR NORTHERN

Eastern or northern white pine (*Pinus strobus*) is sold under two sets of rules. The White Pine Bureau, St. Paul, Minnesota, composed of manufacturers of northern and western white pine, issued in 1917 a book[1] containing the rules of the Northern Pine Manufacturers' Association and the White Pine Association of the Tonawandas, with several photographs of each grade and recommendations as to the use of each grade in house construction.

Tonawanda Rules.—The Tonawanda rules were drawn up by the White Pine Association of the Tonawandas and are used in the Tonawanda wholesale district (Buffalo, Tonawanda, and North Tonawanda, N. Y.) and other eastern markets, principally on material brought by boat from the Georgian Bay District

[1] This book contained also the rules of the Western Pine Manufacturers Association.

and northern Minnesota. The rules contain grades as follows: Upper, Selects, Fine Common, Nos. 1, 2, and 3 Cuts, Nos. 1 and 2 Mouldings, Stained Saps, Star or Shaky Clear, No. 1 Shelving and Dressing, No. 2 Dressing, Nos. 1 and 2 Shelving, Nos. 1, 2, and 3 Barn, and No. 1 Box. The large number of grades allows considerable refinement in grading and provides grades especially suited for certain purposes. Common defects specified are knots, sap, sap stain, and shake. Particular uses for which each grade is suitable are given under each grade.

Northern Pine Manufacturers' Association Rules.—The Northern Pine Manufacturers' Association rules are used by manufacturers throughout the Lake States. Under these rules several different classes of lumber are given, such as finishing, siding, flooring, fencing, common lumber, etc., and under each class several grades are given. In these rules, the better grades suitable for finish are designated as 1, 2, 3 Clear and A, B, C Select, etc.; while the grades more suitable for other purposes are indicated as Nos. 1, 2, and 3 Common, etc. The grades 1, 2, and 3 Clear and A and B Select are frequently not sorted but simply sold together as B Select and Better. These rules differ considerably from the Tonawanda rules, so that a detailed comparison is difficult. Examples are given in the rules under each grade to illustrate different combinations of defects admissible. These rules apply also to Norway pine, spruce, and tamarack cut in the Lake States.

DOUGLAS FIR

Douglas fir is commonly graded under three sets of rules, one for rail shipments, one for domestic cargo shipments, and one for export. The rules are issued by the West Coast Lumbermen's Association and the Pacific Lumber Inspection Bureau.[1] These are separate organizations which coöperate closely. The Pacific Lumber Inspection Bureau is in effect the inspection department of the West Coast Lumbermen's Association.

West Coast Lumbermen's Association Rules ("Rail A").—In the "Rail A" rules, there is a division into a large number of classes of lumber, such as flooring, ceiling, finish, common, dimension, timbers, etc., and a number of grades are given under each class. The principal grades are Nos. 1, 2, 3, and 4 Clear,

[1] A small amount of Douglas fir is also graded by the rules of the Western Pine Manufacturers' Association (see Western Yellow Pine).

Select Common, and Nos. 1, 2, and 3 Common. The grade No. 1 Clear, however, is given only in vertical grain flooring and is practically free from all defects. No. 2 Clear admits a few small defects, which vary with the class of material. The "Clear" grades are finish material; while the "Common" grades are intended for other purposes, such as common boards and timbers. Defects allowable in "Common" grades are naturally more serious than those in the "Clear" grades. Grades of the same name under the different classes of material are somewhat similar as to defects allowed. There are often wide differences, however, both as to sizes and defects allowable due to a certain grade of lumber being adapted to particular use.

Pacific Lumber Inspection Bureau Rules.—Two sets of rules, Export and Domestic, are issued for the use of cargo shippers. The two sets differ both as to classes of material and grades. There are a few grades, however, such as ship plank and flooring, which are practically the same in both sets of rules.

Export Rules.—Several classes of lumber are given under the Export Rules, such as clears, ship plank, deck plank, flooring, ceiling, siding, etc. Some of these classes have several grades and some but one. Boards are graded as No. 2 Clear and Better (Edge and Flat Grain), Merchantable, and Common. Flooring grades are Nos. 1, 2, and 3 Clear Edge Grain, No. 2 Clear and Better, Flat Grain and No. 3 Clear Flat Grain. Stave grades are Nos. 1 and 2. Other products are manufactured in one grade only.

Domestic Rules.—In the domestic rules, a classification is made into rough clears, commons, factory lumber, flooring, ceiling, siding, etc., and under each class several grades are given, as Nos. 1, 2, 3, and 4 Clear, No. 2 Clear and Better, Nos. 3 and 4 Clear, Selected Common, and Nos. 1, 2, and 3 Common. These grades usually differ considerably under each of the different classes. No. 2 Clear and Better in general allows a small number of small tight knots and pitch pockets; No. 3 Clear allows a large number of larger knots and pitch pockets. In the "Common" grades larger knots, pitch pockets, colored sap, and other defects allowable in construction material are admitted. Specifications are given for a considerable number of products, such as tanks, cross-arms, silo and pipe stock, ship planks and decking, mining timber, and railroad ties.

WESTERN WHITE PINE AND WESTERN YELLOW PINE

Pinus monticola and *Pinus ponderosa*

Western (Idaho) white pine and western yellow pine (called western white pine in the manufacturers' rules), larch, and Douglas fir cut in the Inland Empire (western Montana, Idaho, and eastern Washington and Oregon) are graded under the rules of the Western Pine Manufacturers' Association. They are nearly the same as the Northern Pine Manufacturers' Association rules for northern white pine; the higher grades of the Northern Pine Manufacturers' rules are omitted, however, and slight changes have been made in specifying defects, so as to adapt the rules to the western species.

The grades designated as "Clear" and "A Select," in the Northern Pine rules, are omitted in these rules, so that "B Select and Better" is the highest grade of material. It admits small sound knots, slight stain, and slight traces of pitch or small season checks. Several examples are given in the rules under each grade for illustration.

Western yellow pine throughout the southern Rockies, the middle Rockies, and the Black Hills is also graded under the rules of the Western Pine Manufacturers' Association. Western yellow pine cut in California and sold as California white pine is graded under the rules of the California White and Sugar Pine Association.[1]

SUGAR PINE

Sugar pine in California is graded under the rules of the California White and Sugar Pine Association. The rules are patterned after those of the Northern Pine Manufacturers' Association. The highest grade, Nos. 1 and 2 Clear, is as nearly equivalent to the northern white pine B Select and Better as the timber characteristics of the two regions permit. No. 3 Clear is a cutting-up grade. Other grades are similar to the northern pine grades. California white pine (western yellow pine) is also graded under the California rules. Sugar pine and California white pine are separated in the Clear and Select grades but not in the Common grades which also include white and red fir. The common grades are used largely by California box manufacturers.

[1] See Sugar Pine.

HEMLOCK

Western Hemlock.—In the Pacific Northwest western hemlock is graded under the "Rail A" rules of the West Coast Lumbermen's Association and the Domestic and Export rules of the Pacific Lumber Inspection Bureau. In each rule the grades are practically the same as the Douglas fir grades; but hemlock products are limited to flooring, ceiling, partition, siding, finish, boards, shiplap, and dimension. With the exception of timbers, western hemlock is made into the same forms of ordinary building lumber and planing-mill products as Douglas fir. In fact, in the grade of No. 3 Common for Douglas fir boards, dimension, plank, and small timbers, part or all hemlock is allowed. Douglas fir mining timber may be 15 per cent. hemlock. In No. 3 Clear flat flooring and No. 2 Clear and Better ceiling, partition, and siding, 15 per cent. may be hemlock. In No. 4 Clear flooring and Nos. 3 and 4 Clear ceiling, partition, and siding, hemlock in any quantity is permitted.

Eastern Hemlock.—In the Lakes States, eastern hemlock is graded under the Northern Hemlock and Hardwood Manufacturers' Association rules and the Michigan Hardwood Manufacturers' Association rules. Both sets of rules are modeled after the white pine rules used in the Lake States. The two rules differ somewhat but the common grades are similar. Finish has one or two grades. Boards and Strips are graded as Nos. 1, 2, 3, and 4 Common; and Piece Stuff or Dimension, as Nos. 1, 2, and 3. One rule has a No. 5 Board, the other a No. 4 Dimension. The other products made are flooring, ceiling, shiplap, and drop siding, but no grades are listed.

Hemlock in New England, New York, and Pennsylvania is graded largely by local rules, although Lake States grades are sometimes used in New York. In the local rules the grade "Merchantable" is frequently used and sometimes the grade "Mill Run Mill Culls Out." In West Virginia and North Carolina the Spruce Manufacturers' Association rules[1] are followed to some extent.

CYPRESS

Grading rules for cypress are issued by the Southern Cypress Manufacturers' Association and the National Hardwood Lumber Association.

[1] See Eastern Spruce.

The present rules of the Southern Cypress Manufacturers' Association were designed especially for selling to retailers. The finish grades are A, B, and C, A having a perfect heart face. The grades for boards are Select Common, Heart Select Common, Nos. 1 and 2 Common, Box, and Peck. Flooring, siding, partition, and ceiling grades are A, B, C, and D. One grade each is provided for tank stock, switch ties, cross ties, panel stock, shorts, battens, squares, car roofing, car siding, and car lining. The factory grades are Factory Selects and Shop.

The National Hardwood Lumber Association rules for cypress are intended to serve both the retail and factory trade. The grades partake of the nature of both hardwood and softwood rules. The grades for rough lumber are Firsts and Seconds, Selects, Nos. 1 and 2 Shop, Nos. 1 and 2 Common, Nos. 1 and 2 Boxing, and Peck. Dressed finish is graded A, B, C, and D Finish. Siding, flooring, ceiling, and partition grades are A, B, C, and D. In addition there is one grade each for tank stock, car roofing, car siding, car lining, battens, and turning squares.

REDWOOD

Redwood is graded by the rules of the California Redwood Association. The grades are divided into two classifications, Uppers and Sundry Common. Uppers are the finishing grades, and include Clear, Sap Clear, Select, and Standard. The Sundry Common grades are Extra Merchantable, Merchantable, Construction, Shop Common, Inch Shop Common, Subflooring, and Sheathing Stock. Merchantable is not a distinct grade. It is made up of 60 per cent. "Extra Merchantable" and the balance "Construction." The Shop Common grades are for factory use.

These rules are used mostly for western trade, and a somewhat different set of rules is used for eastern trade. However, the eastern rules are not published by the Association but can be found only in price lists and are therefore difficult to refer to. The eastern grades are as follows:

Product	*Grade*
Finish	Clear, A and B
Ceiling	Clear, A and B
Drop siding	Clear, A and B
Rustic	Clear, A and B

Product	*Grade*
Porch flooring	Clear, A and B
Car siding	Clear, A and B
Car roofing	Clear, A and B
Siding (bevel, colonial, bungalow)	Clear, A and B
Clapboards	Clear and Clear Sap
Pattern stock	Vertical Grain, Clear, and B
Factory lumber	Shop
Squares	Clear and A
Tank stock	Clear and Select
Silo stock	Clear and Select
Pipe staves	Clear and Select
Boards and dimension	Merchantable and Extra Merchantable

The Bigtree or Sequoia, of the same family as redwood, is sometimes cut for lumber, and this is often graded by the Redwood rules.

EASTERN SPRUCE

Eastern spruce is graded in the Lake States under the rules of the Northern Pine Manufacturers' Association.

In the New England States there is no published set of rules in use, but custom has brought about a general understanding of what is "Merchantable" and "Box." Sometimes spruce box lumber in New England is sold round edge mixed with round edge white pine.

In the Adirondacks no published rules are available, but here again custom has made the following grades, which are currently quoted in New York City: No. 1 and Clear, No. 2, No. 3, Mill Run Mill Culls Out, and Mill Culls.

In West Virginia and North Carolina the rules largely used are those of the Spruce Manufacturers' Association, which provide for Firsts and Seconds (Clears), Selects, Dressing (Select Merchantable), Merchantable, Box, and Mill Culls.

SITKA SPRUCE

Sitka spruce is graded under the "Rail A" rules of the West Coast Lumber Manufacturers' Association and the Domestic and Export rules of the Pacific Lumber Inspection Bureau. The "Rail A" and Domestic rules have the following identical grades for spruce: B and Better finish, Factory Select and Better, Nos. 1 and 2 Shop Common, Inch Shop Common, and Nos.

1, 2, and 3 Box. As these grades indicate, Sitka spruce is used largely by door and box manufacturers. In addition, the "Rail A" list provides for B and Better flooring, ceiling, partition, stepping, car siding and car roofing, A, B, and C bevel siding, Select and No. 1 Common, boards, dimension, planks, small timbers, and one grade each for squares, molding stock, panel stock, ladder stock, piano posts and sounding boards, and airplane stock. The Export list provides No. 2 Clear and Better, No. 3 Clear and Better Shelving, Merchantable lumber and timber, and Merchantable Box.

ENGELMANN SPRUCE

Engelmann spruce is graded under the rules of the Western Pine Manufacturers' Association.

TAMARACK AND LARCH

Throughout the Lake States tamarack is graded under the rules of the Northern Pine Manufacturers' Association.

In the Inland Empire (Idaho, Montana, and eastern Washington and Oregon) the rules of the Western Pine Manufacturers' Association are used for larch.

SOUTHERN RED CEDAR

(*Juniperus virginiana*)

Red cedar lumber is usually sold log run, as there are no definite rules established.

WESTERN RED CEDAR

Western red cedar is graded under the rules of the West Coast Lumber Manufacturers' Association and the Pacific Lumber Inspection Bureau Domestic Rules. The rules covering western red cedar in these two sets of rules are nearly the same. The Bevel Siding grades are Clear A and B. Finish and boards are graded as No. 2 Clear and Better and Nos. 1 and 2 Common. One grade each is provided for bungalow or colonial siding, porch decking, flooring, porch columns, and newels. In the Inland Empire a few grades of the Western Pine Manufacturers' Association are used to a very small extent.

SOUTHERN WHITE CEDAR

No standard rule is in general use for southern white cedar. Planking for boats is usually bought under the term "Boat Boards." This is sound lumber in which knots are allowed, provided they are tight. The Navy Department has prepared very satisfactory rules for southern white cedar boat boards.

PORT ORFORD CEDAR

The Domestic rules of the Pacific Lumber Inspection Bureau provide the following grades for Port Orford cedar: Nos. 1 and 2 Clear (B and Better), Selects, No. 3 Clear, Nos. 1 and 2 Shop, Common and No. 3 Boards, and Dimension. The products graded are boat boards, flooring, ceiling, siding, casing, base, partition, panel stock, shiplap, grooved roofing, and cribbing. The finishing and shop grades are similar to those for sugar pine, California white pine, and Sitka spruce, with which Port Orford cedar competes.

LODGEPOLE PINE

In the Inland Empire the rules of the Western Pine Manufacturers' Association are used for lodgepole pine. Very little of this species is graded, however, the great bulk of it being used for mine timbers and local consumption, for which there are no grading rules in general use. In the Rocky Mountain regions it is cut almost entirely by small mills, and no association rules are in general use for such material.

WHITE FIR

White fir, including several firs of minor importance, is sold in California under the common grades of the California White and Sugar Pine Manufacturers' Association; in the Inland Empire it is sold under the common grades of the Western Pine Manufacturers' Association; and in Washington and Oregon it is admitted in the Douglas fir grade of No. 3 Common Boards.

CHAPTER VII

LUMBER PRODUCED AND USED IN THE UNITED STATES

LUMBER PRODUCED BY MILLS

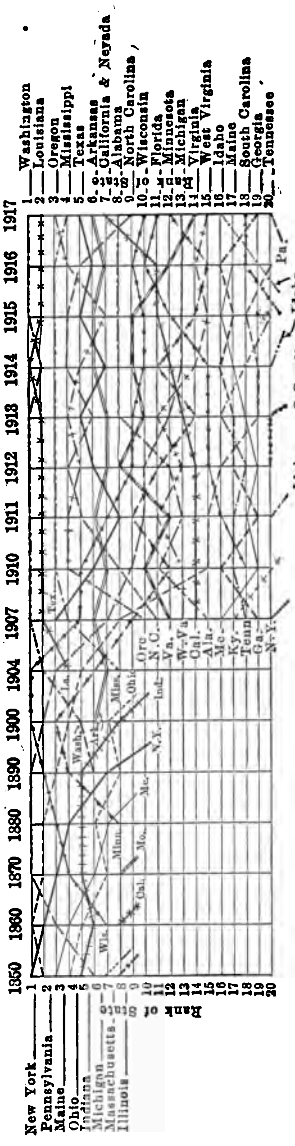


Fig. 104.—Relative rank of the States leading in the production of lumber since 1850.

The annual lumber production of the United States is approximately 40 billion feet. The cut reported for each of a number of years since 1899 and the number of active mills reporting are shown in Table 23. The total cut for the whole United States is given first, followed by the cut for each State, in the order of the quantity cut in 1915.[1] The high point was reached in 1909. There has been little variation in the total cut in the last few years.

Figure 104 gives the relative rank of the States leading in the production of lumber since 1850.[2] The rise and fall of the various States as lumber producers follows the shifting center of the lumber industry as forests are cut out and new areas are opened up. New York, Pennsylvania, Michigan, and Wisconsin all have held first place as lumber producers. Washington and Louisiana have ranked first and second respectively for the last ten years, except in 1914, when the order

[1] See *Bulletin* No. 506, Department of Agriculture, "Production of Lumber, Lath, and Shingles in 1915," by J. C. Nellis.

[2] Data are not available to make the diagram complete.

was reversed. The large proportion of the total 1915 cut produced in Washington and Louisiana is strikingly shown in Fig. 105, which gives graphically the 1915 cut by States.

The quantity of each kind of lumber cut annually for a number of years since 1899 is given in Table 24. Yellow pine, which

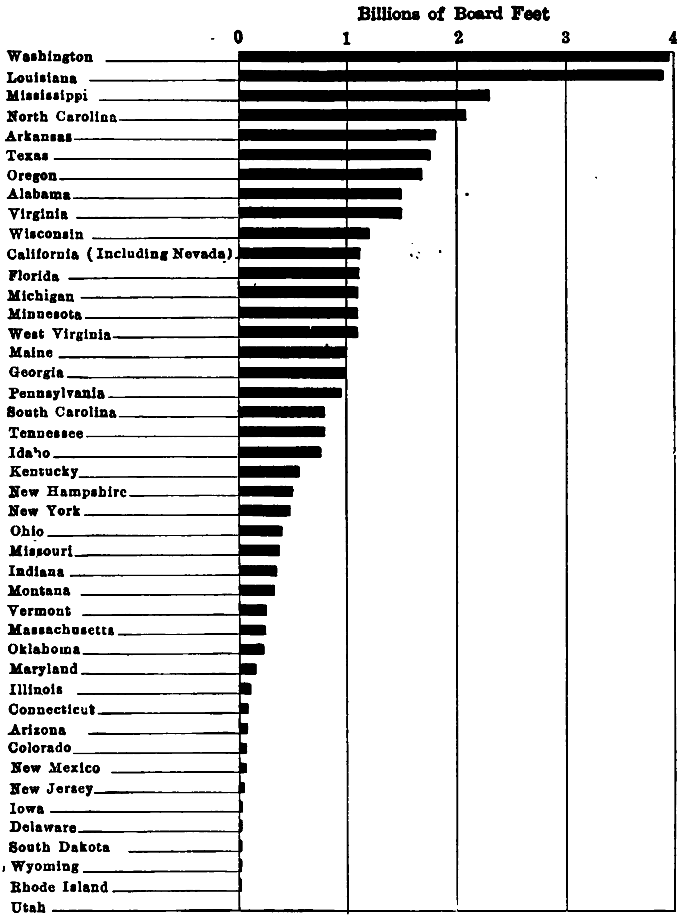


FIG. 105.—Computed total lumber production in 1915, by States.

includes the longleaf, shortleaf, and loblolly pines of the southern States, makes up about one-third of the annual lumber cut. Five species, yellow pine, Douglas fir, oak, white pine, and hemlock, have been the leaders in quantity production for the last twenty

TABLE 23.—TOTAL NUMBER OF ACTIVE SAWMILLS REPORTING, AND

State	1915 (29,951 mills)[1]	1914 (27,506 mills)[2]	1913 (21,668 mills)	1912 (29,005 mills)	1911 (28,107 mills)[3]
	M feet b. m.	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*
United States......	[4]37,011,656	[4]37,346,023	[4]38,387,009	[4]39,158,414	[4]37,003,207
Washington...........	3,950,000	3,946,189	4,592,053	4,099,775	4,064,754
Louisiana.............	3,900,000	3,956,434	4,161,560	3,876,211	3,566,456
Mississippi............	2,300,000	2,280,966	2,610,581	2,381,898	2,041,615
North Carolina........	2,090,000	2,227,854	1,957,258	2,193,308	1,798,724
Arkansas..............	1,800 000	1,796,780	1,911,647	1,821,811	1,777,303
Texas.................	1,750,000	1,554,005	2,081,471	1,902,201	1,681,080
Oregon................	1,690,000	1,817,875	2,098,467	1,916,160	1,803,698
Alabama..............	1,500,000	1,494,732	1,523,936	1,378,151	1,226,212
Virginia...............	1,500,000	1,488,070	1,273,953	1,569,097	1,359,790
Wisconsin.............	1,210,000	1,391,001	1,493,353	1,498,876	1,761,986
California.............	[5]1,130,000	1,303,183	1,183,380	1,203,059	1,207,561
Florida................	1,110,000	1,073,821	1,055,047	1,067,525	983,824
Michigan..............	1,100,000	1,214,435	1,222,983	1,488,827	1,466,754
Minnesota.............	1,100,000	1,312,230	1,149,704	1,436,726	1,485,015
West Virginia..........	1,100,000	1,118,480	1,249,559	1,318,732	1,387,786
Maine.................	1,000,000	992,594	834,673	882,128	828,417
Georgia................	1,000,000	1,026,191	844,284	941,291	801,611
Pennsylvania..........	950,000	864,710	781,547	992,180	1,048,606
South Carolina.........	800,000	701,540	752,184	816,930	584,872
Tennessee.............	800,000	885,035	872,311	932,572	914,579
Idaho.................	777,000	763,508	652,616	713,575	765,670
Kentucky..............	560,000	596,392	541,531	641,296	632,415
New Hampshire........	500,000	482,744	309,424	479,499	388,619
New York.............	475,000	486,195	457,720	502,351	526,283
Ohio..................	400,000	286,063	414,943	499,834	427,161
Missouri..............	350,000	370,571	416,608	422,470	418,586
Indiana...............	350,000	298,571	332,993	401,017	360,613
Montana..............	328,000	317,842	357,974	272,174	228,416
Vermont..............	260,000	249,608	194,647	235,983	239,254
Massachusetts.........	250,000	143,094	224,580	259,329	273,317
Oklahoma.............	230,000	200,594	140,284	168,806	143,869
Maryland.............	165,000	162,097	140,469	174,320	144,078
Illinois................	110,000	66,227	102,902	122,528	96,651
Connecticut...........	90,000	81,883	93,730	109,251	124,661
Arizona...............	75,915	78,667	77,363	76,287	73,139
Colorado..............	74,500	102.117	74,602	88,451	95,908
New Mexico...........	65,787	57,167	65,818	82,650	83,728
New Jersey............	45,000	48,748	27,248	34,810	28,639
Iowa..................	35,000	11,443	21,676	46,593	59,974
Delaware..............	25,000	25,517	18,039	28,285	23,853
South Dakota.........	22,562	18,744	19,103	20,986	13,046
Wyoming.............	17,000	11,852	12,940	13,560	33,309
Rhode Island..........	15,000	15,902	14,984	14,421	9,016
Utah..................	10,892	8,680	5,403	9,055	10,573
All other States........	(6)	[7]15,672	[7]19,461	[7]22,525	[7]11,786

[1] Figures shown are computed totals for 1915.
[2] Custom mills excluded.
[3] Includes also exclusive lath and shingle mills reporting (1,500 estimated).
[4] Mills cutting less than 50 M feet per year excluded.
[5] Includes cut of two mills in Nevada.

QUANTITY OF LUMBER REPORTED, BY STATES, 1899–1915

1910 (31,934 mills)[3]	1909 (46,584 mills)	1908 (31,231 mills)[3]	1907 (28,850 mills)[3]	1906 (22,398 mills)	1904 (18,277 mills)[2]	1899 (31,833 mills)
M feet b. m.	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*
[4]40,018,282	44,509,761	33,224,369	40,256,154	37,550,736	[4]34,135,139	35,084,166
4,097,492	3,862,916	2,915,928	3,777,606	4,305,053	2,485,628	1,429,032
3,733,900	3,551,918	2,722,421	2,972,119	2,796,395	2,459,327	1,115,366
2,122,205	2,572,669	1,861,016	2,094,485	1,840,250	1,727,391	1,206,265
1,824,722	2,177,715	1,136,796	1,622,387	1,222,974	1,318,411	1,286,638
1,844,446	2,111,308	1,656,991	1,988,504	1,839,368	1,680,536	1,623,987
1,884,134	2,099,130	1,524,008	2,229,590	1,741,473	1,406,473	1,232,404
2,084,633	1,898,995	1,468,158	1,635,563	1,604,894	987,107	734,538
1,465,623	1,691,001	1,152,079	1,224,967	1,009,783	1,243,988	1,101,386
1,652,192	2,101,716	1,198,725	1,412,477	1,063,241	949,797	959,119
1,891,291	2,025,038	1,613,315	2,003,279	2,331,305	2,623,157	3,389,166
1,254,826	1,143,507	996,115	1,345,943	1,348,559	1,077,499	737,035
992,091	1,201,734	730,906	839,058	888,137	812,693	790,373
1,681,081	1,889,724	1,478,252	1,827,685	2,094,279	2,006,670	3,018,338
1,457,734	1,561,508	1,286,122	1,660,716	1,794,144	1,942,248	2,342,338
1,376,737	1,472,942	1,097,015	1,395,979	976,173	855,889	778,051
860,273	1,111,565	929,350	1,103,808	1,088,747	863,860	784,647
1,041,617	1,342,249	904,668	853,697	831,675	1,135,910	1,311,917
1,241,199	1,462,771	1,203,041	1,734,729	1,620,881	1,738,972	2,333,278
706,831	897,660	560,888	649,058	566,928	609,769	466,429
1,016,475	1,223,849	790,642	894,968	634,587	775,885	950,958
745,984	645,800	518,625	513,788	418,944	211,447	65,363
753,556	860,712	658,539	912,908	661,299	586,371	774,651
443,907	649,606	606,760	754,023	539,259	491,591	572,447
506,074	681,440	781,391	848,894	810,949	581,976	878,448
490,039	542,904	459,259	529,087	438,775	420,905	990,497
501,691	660,159	458,938	548,774	507,084	553,940	723,754
422,963	556,418	411,868	504,790	447,808	563,853	1,036,999
319,089	308,582	311,533	343,814	328,727	236,430	255,695
284,815	351,571	304,017	373,660	329,422	337,238	375,809
239,206	361,200	384,526	364,231	354,483	262,467	344,190
164,663	225,730	158,756	140,015	49,737	32,730	22,104
154,554	267,939	168,534	213,786	219,098	166,469	183,711
113,506	170,181	123,319	141,317	141,374	211,545	388,469
126,463	168,371	137,855	140,011	124,880	69,376	108,093
72,655	62,731	43,287	72,134	56,960	55,601	36,182
121,398	141,710	117,036	134,239	110,212	141,914	133,746
83,544	91,987	79,439	113,204	103,079	81,113	30,880
36,542	61,620	34,930	39,942	36,253	44,058	74,118
75,446	132,021	97,242	144,271	163,747	281,521	352,411
46,642	55,440	41,184	50,892	44,487	30,416	35,955
16,340	31,057	25,859	34,841	22,634	13,705	31,704
30,931	28,602	18,822	17,479	13,213	7,990	16,963
14,392	25,489	30,528	32,855	21,528	15,398	18,528
11,786	12,638	15,059	14,690	7,768	12,630	17,548
[7]12,594	[7]15,946	[8]10,627	[8]5,891	[9]170	[10]23,245	[10]24,646

[6] Kansas and Nebraska mills reported less than 50 M feet each, and these States are therefore omitted.
[7] Includes Kansas, Nebraska, and Nevada.
[8] Includes Kansas and Nevada.
[9] Kansas.
[10] Includes Alaska, Kansas, Nebraska, Nevada, and North Dakota in 1899.

TABLE 24.—QUANTITY OF EACH KIND OF LUMBER REPORTED, 1899–1914, AND COMPUTED TOTAL 1915 PRODUCTION

Kind of wood	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1904	1899
	M feet b. m.	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*	*M feet b. m.*
Total....	[1]37,011,656	37,346,023	38,387,009	39,158,414	37,003,207	40,018,282	44,509,761	33,224,369	40,256,154	37,550,736	[2]34,135,139	[2]35,084,166
Yellow pine...	14,700,000	14,472,804	14,839,363	14,737,052	12,896,706	14,143,471	16,277,185	11,236,372	13,215,185	11,661,077	11,521,681	9,657,676
Douglas fir...	4,431,249	4,763,693	5,556,096	5,175,123	5,054,243	5,203,644	4,856,378	3,675,114	4,748,872	4,969,843	2,928,409	1,736,507
Oak..........	2,970,000	3,278,908	3,211,718	3,318,952	3,098,444	3,522,098	4,414,457	2,771,511	3,718,760	2,820,393	2,902,855	4,438,027
White pine...	2,700,000	2,632,587	2,568,636	3,138,227	3,230,584	3,352,183	3,900,034	3,344,921	4,192,708	4,583,727	5,332,704	7,742,391
Hemlock.....	2,275,000	2,165,728	2,319,982	2,426,554	2,555,308	2,836,129	3,051,399	2,530,843	3,373,016	3,537,329	3,268,787	3,420,673
Spruce.......	1,400,000	1,245,614	1,046,816	1,238,600	1,261,728	1,449,912	1,748,547	1,411,992	1,726,797	1,644,987	1,303,886	1,448,091
Western yellow pine....	1,293,985	1,327,365	1,258,528	1,219,444	1,330,700	1,562,106	1,499,985	1,275,550	1,527,195	1,386,777	1,290,626	945,432
Cypress......	1,100,000	1,013,013	1,097,247	997,227	981,527	935,659	955,635	743,297	757,639	839,276	749,592	495,836
Maple........	900,000	909,763	901,487	1,020,864	951,667	1,006,637	1,106,604	874,983	939,073	882,878	587,558	633,466
Red gum.....	655,000	675,380	772,514	694,260	582,967	610,208	706,945	589,347	689,200	453,678	523,990	285,417
Chestnut.....	490,000	540,591	505,802	554,230	529,022	535,049	663,891	539,341	653,239	407,379	243,537	206,688
Yellow poplar	464,000	519,221	620,176	623,289	659,475	734,926	858,500	654,122	862,849	677,670	853,554	1,115,242
Redwood.....	420,294	535,199	510,271	496,796	489,768	543,493	521,630	404,802	569,450	659,678	519,267	360,167
Cedar........	420,000	499,903	358,444	329,000	374,925	415,039	346,008	272,764	251,002	357,845	223,035	232,978
Birch........	415,000	430,667	378,739	388,272	432,571	420,769	452,370	386,367	387,614	370,432	224,009	132,601
Larch........	375,000	358,561	395,273	407,064	368,216	382,514	421,214	382,466	324,509	289,473	31,784	50,619
Beech........	360,000	376,464	365,501	435,250	403,881	437,325	511,244	410,072	430,005	275,661	([3])	([3])
Basswood....	260,000	264,656	257,102	296,717	304,621	344,704	399,151	319,505	381,088	376,838	228,041	308,069
Elm.........	210,000	214,294	214,532	262,141	236,108	265,107	347,456	273,845	260,579	224,795	258,330	456,731
Ash..........	190,000	189,499	207,816	234,548	214,398	246,035	291,209	225,367	252,040	214,460	169,178	269,120
Cottonwood..	180,000	195,198	208,938	227,477	198,629	220,305	265,600	232,475	293,161	269,458	321,574	415,124
Tupelo.......	170,000	124,480	120,420	122,545	98,142	92,071	96,676	69,170	68,842	47,882	([3])	([3])
White fir.....	125,048	112,627	88,109	122,613	124,307	132,327	89,318	98,120	146,508	104,329	([3])	([3])
Sugar pine....	117,701	136,159	149,926	132,416	117,987	103,165	97,191	99,809	115,005	133,640	([3])	53,558
Hickory......	100,000	116,113	162,980	278,757	240,217	272,252	333,929	197,372	203,211	148,212	106,824	96,636
Balsam fir....	100,000	125,212	93,752	84,261	83,375	74,580	108,702	69,956	53,339	([3])	([3])	([3])
Walnut.......	90,000	25,573	40,565	43,083	38,293	36,449	46,108	43,681	41,490	48,174	31,455	38,681
Lodgepole pine........	26,486	18,374	20,106	22,039	33,014	26,634	23,733	([3])	([3])	([3])	([3])	([3])
Sycamore.....	25,000	22,773	30,804	49,468	42,836	45,063	56,511	43,332	46,044	([3])	18,002	29,715
All other kinds	47,893	55,624	85,366	82,145	69,548	68,428	62,151	47,873	27,734	164,845	496,461	[2]514,721

[1] Computed total 1915 production by kinds of wood.
[2] Includes lumber cut in Alaska.
[3] Not separately reported.

years, and have furnished about three quarters of the total annual cut. Figure 106 shows the relative rank of the various species in the production of lumber for a number of years. The lumber production in 1915 by species is shown diagrammatically in Fig. 107.[1]

TABLE 25.—REPORTED PRODUCTION OF LUMBER 1909, 1912, 1913, 1914, AND 1915 COMPUTED TOTALS, BY CLASSES OF MILLS

Class	Year	Mills		Quantity reported	
		Number reporting	Per cent.	M ft. b. m.	Per cent.
Class 5: 10,000 M and over per year....	1909	888	2.11	19,126,223	43.09
	1912	926	3.19	21,259,274	54.29
	1913	974	4.50	23,211,667	60.47
	1914	867	3.15	20,934,446	56.06
	[1] 1915	846	2.82	20,669,746	55.84
Class 4: 5,000 M to 9,999 M per year...	1909	783	1.86	5,291,606	11.92
	1912	608	2.10	4,311,063	11.01
	1913	740	3.41	4,303,122	11.21
	1914	547	1.99	3,910,370	10.47
	[1] 1915	453	1.51	3,224,448	8.71
Class 3: 1,000 M to 4,999 M per year...	1909	5,443	12.95	10,068,592	22.69
	1912	3,747	12.92	7,009,608	17.90
	1913	3,265	15.07	6,319,753	16.46
	1914	3,291	11.97	6,078,730	16.28
	[1] 1915	3,191	10.65	6,201,864	16.76
Class 2: 500 M to 999 M per year......	1909	6,468	15.39	4,315,636	9.72
	1912	4,420	15.24	2,951,068	7.54
	1913	3,148	14.53	2,049,642	5.34
	1914	4,261	15.49	2,780,184	7.44
	[1] 1915	4,198	14.02	2,941,264	7.95
Class 1: 50 M to 499 M per year.......	1909	28,459	67.69	5,582,738	12.58
	1912	19,304	66.55	3,627,401	9.26
	1913	13,541	62.49	2,502,825	6.52
	1914	18,540	67.40	3,642,293	9.75
	[1] 1915	21,263	70.99	3,974,334	10.74
All classes........................	[2] 1909	42,041	100.00	44,384,795	100.00
	1912	29,005	100.00	39,158,414	100.00
	1913	21,668	100.00	38,387,009	100.00
	1914	27,506	100.00	37,346,023	100.00
	[1] 1915	29,951	100.00	37,011,656	100.00

[1] The data here shown for 1915 are the computed totals by classes of mills.
[2] The total for 1909 differs from that shown in other tables because 4,543 mills, cutting a total of 124,966,000 feet, or less than 50 M feet each, are omitted in this table.

The proportion of the total cut produced by the different sized mills is given in Table 25[1]. It will be noted that the largest mills, *i.e.*, those cutting 10 billion board feet and over per year, produced over half the cut in 1915, although they made up less than 3 per cent. of the total number of mills; while the mills cutting from 50,000 to 499,000 board feet per year, produced

[1] See Department of Agriculture, *Bulletin* No. 506, "Production of Lumber, Lath, and Shingles in 1915," by J. C. Nellis.

only about 10 per cent. of the cut and made up 70 per cent. of the total number of mills.

LUMBER USED IN THE MANUFACTURE OF WOODEN PRODUCTS

The lumber-working plants, of all classes, consume annually some 24½ billion feet of wood. This is about 60 per cent. of the annual lumber production. The material is mostly lumber, but includes comparatively small quantities of veneer, bolts, and dimension stock.

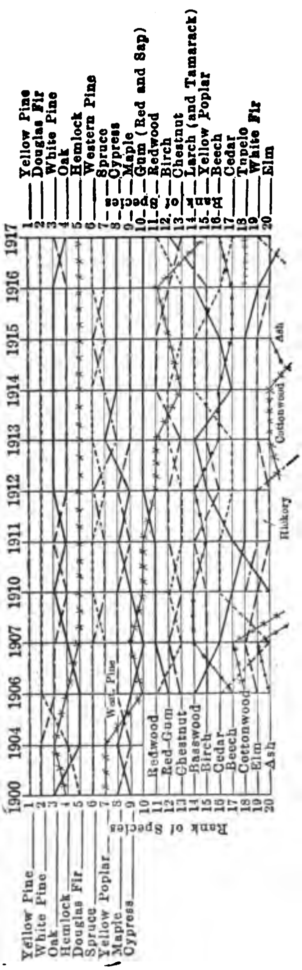


FIG. 106.—Relative rank of the species leading in the production of lumber since 1900.

The average annual consumption of wood by the wood-working industries in the United States is shown in Table 26.[1] The basic data were secured by a series of State wood-using industry studies conducted by the Forest Service in coöperation with State organizations. Although the State studies were begun in 1909 and were not completed until 1913, a period of twelve months was made the basis for the statistics for each State, and the final figures for the whole country presented in Table 26 are a very good average of the demand of each industry and of the demand for each kind of wood under normal conditions.

Lumber usually is remanufactured to a greater or less extent before use, and in Table 26 the product of the sawmill is not considered. However, planing mills operated in connection with sawmills manufacture large quantities of flooring, ceiling, siding, finish, and other patterns which really are finished products, and such material accordingly is included.

[1] See Department of Agriculture, *Bulletin* No. 605, "Lumber used in the manufacture of Wooden Products," by J. C. Nellis.

About 40 per cent. of the annual lumber cut is not worked by planing mills or factories into finished products. About one-fifth of this (in normal times) is exported, and the rest is used in

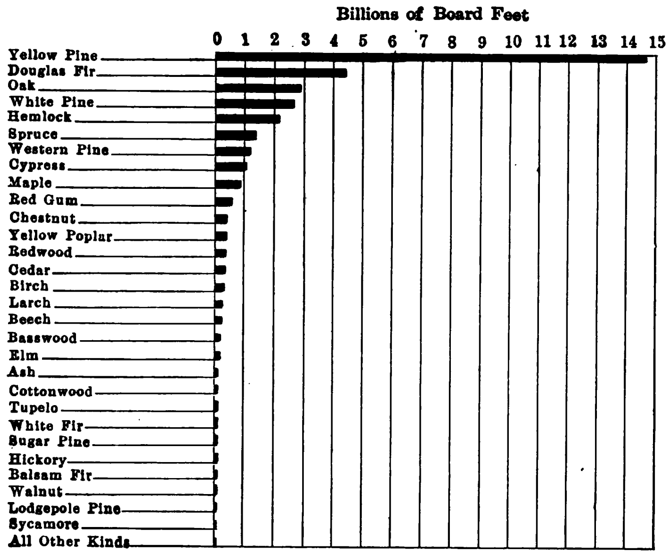


FIG. 107.—Computed total lumber production in 1915, by kinds of wood.

general building and rough construction. Although all construction lumber requires cutting to length to make it fit into place, this was not considered in the class of wood-working industries.

TABLE 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD

Industry	Kind of wood		
	Total	Yellow pine	White pine
	Feet b. m.	*Feet b. m.*	*Feet b. m.*
All industries	24,576,556,564	8,610,685,624	3,112,698,017
Planing-mill products, sash, doors, blinds, and general millwork	13,428,862,066	6,447,780,805	1,543,345,756
Boxes and crates	4,550,016,430	1,044,993,123	1,131,969,940
Car construction	1,262,090,371	678,114,162	75,382,166
Furniture	944,677,807	18,926,400	9,332,808
Vehicles and vehicle parts	739,144,483	31,205,478	1,675,277
Woodenware, novelties, and dairymen's, poulterers', and apiaristers' supplies	405,286,436	18,566,406	47,744,797
Agricultural implements	321,239,336	98,453,396	8,243,440
Chairs and chair stock	289,790,560	20,000	815,068
Handles	280,234,571	67,000	25,500
Musical instruments	260,195,026	2,107,994	9,394,820
Tanks and silos	225,619,686	41,291,700	17,007,600
Ship and boat building	199,598,228	65,698,652	14,256,006
Fixtures	187,132,848	11,612,365	4,864,150
Caskets and coffins	153,394,557	11,970,650	33,170,942
Refrigerators and kitchen cabinets	137,616,266	7,872,931	8,613,186
Matches and toothpicks	85,442,111	....	73,059,611
Laundry appliances	79,502,040	1,397,000	3,026,870
Shade and map rollers	79,291,575	1,150,000	61,450,000
Paving material and conduits	76,067,000	65,092,000	1,850,006
Trunks and valises	74,667,997	15,277,990	7,299,500
Machine construction	69,459,430	22,461,088	5,405,405
Boot and shoe findings	66,240,200	....	....
Picture frames and molding	65,477,783	5,498,000	5,812,300
Shuttles, spools, and bobbins	65,148,190	....	130,000
Tobacco boxes	64,127,476	....	199,425
Sewing machines	59,946,527	65,000	....
Pumps and wood pipe	55,826,938	373,230	12,524,006
Pulleys and conveyors	35,862,900	250,000	285,000
Professional and scientific instruments	35,070,928	46,600	601,670
Toys	28,926,552	....	2,367,131
Gates and fencing	27,450,540	6,765,000	3,883,500
Sporting and athletic goods	25,191,907	943,000	805,300
Patterns and flasks	24,299,403	1,951,447	17,854,635
Bungs and faucets	21,112,342	....	287,000
Plumbers' woodwork	20,313,450	262,250	786,500
Electrical machinery and apparatus	18,188,910	1,264,900	3,022,700
Mine equipment	16,987,697	1,263,000	239,000
Brushes	12,878,986	....	75,000
Dowels	11,980,500	....	25,000
Elevators	10,018,680	3,622,868	1,692,450
Saddles and harness	9,218,000	....	10,000
Playground equipment	9,064,812	1,448,012	42,000
Butchers' blocks and skewers	8,197,050	....	200,000
Clocks	7,894,249	926,571	476,064
Signs and supplies	6,888,366	428,856	3,266,950
Printing material	5,324,794	337,000	11,550
Weighing apparatus	5,021,550	1,180,750	168,000
Whips, canes, and umbrella sticks	4,946,880	....	....
Brooms and carpet sweepers	2,277,334	....	....
Firearms	2,093,901	....	....
Artificial limbs	687,080	....	....
Tobacco pipes	489,515	....	....
Airplanes	74,300	....	....

BY THE WOOD-WORKING INDUSTRIES OF THE U. S.

Kind of wood—*Continued*

Douglas fir	Oak	Maple	Spruce	Red gum	Hemlock
Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
2,273,788,484	1,983,584,491	919,420,274	805,050,195	797,343,658	708,752,769
1,991,177,352	501,367,772	317,634,231	350,528,295	121,366,583	442,050,165
7,349,840	56,362,111	96,831,648	335,935,643	402,121,640	203,526,091
86,544,784	305,276,814	5,789,298	8,799,060	1,035,640	12,455,379
11,387,790	431,053,289	87,571,456	2,270,500	102,237,867	7,053,446
930,610	212,918,361	35,863,267	835,650	26,650,314	448,678
2,005,175	7,716,860	38,255,880	28,591,148	8,358,296	2,136,522
2,537,250	69,346,130	48,319,210	2,623,500	11,976,000	1,257,400
65,000	135,269,118	47,264,747	10,000	8,790,280	216,000
247,200	12,458,472	41,238,446	18,000	6,654,300	500,000
480,400	20,638,480	45,482,775	29,144,150	9,243,825	615,600
89,705,322	5,042,401	200,000	10,233,500	1,085,000	1,777,000
44,342,081	32,382,311	1,014,167	7,783,980	164,000	4,745,775
5,512,310	62,681,744	20,701,026	2,016,816	5,491,170	473,300
6,000	7,544,255	110,000	1,700,000	7,010,520	1,985,000
543,600	31,351,521	6,375,242	5,555,690	13,483,400	6,934,872
....	....	1,200,000	750,000	....	....
184,500	427,500	14,219,000	2,301,000	3,395,000	1,300,000
3,000,000	294,000	879,925	7,063,000	2,065,200	....
3,500,000	....	....	....	....	....
....	4,500	5,047,000	1,759,850	1,783,005	7,000,000
985,100	8,295,864	3,597,981	729,775	206,500	3,268,191
....	3,000	54,050,000	....	....	....
6,000	16,043,423	309,150	325,000	7,675,040	....
....	39,000	13,531,450	....	270,000	....
....	403,200	96,450	....	6,898,270	....
....	19,106,250	324,148	....	20,774,280	....
21,351,480	565,800	1,706,000	....	3,089,628	....
129,000	7,343,500	2,436,000	177,000	19,677,500	200,000
30,000	372,100	4,425,167	16,000	75,500	....
....	1,444,057	3,964,400	1,300	523,000	241,000
805,000	2,640,700	140,000	1,071,000	....	5,152,000
85,000	2,497,559	4,913,815	191,800	150,000	180,000
54,090	182,200	118,150	478,238	1,000	580,600
....	250,000	854,900	110,000	325,000	....
....	14,031,200	388,300	....	416,000	....
138,000	4,936,000	1,190,650	1,980,700	202,500	257,600
....	4,826,472	949,200	....	250,100	2,328,750
....	90,900	1,911,897	....	284,800	....
....	77,000	1,354,500	....	15,000	....
415,200	956,200	1,562,262	73,000	....	1,003,800
130,500	1,248,000	1,450,500	....	1,078,500	....
1,000	2,576,800	854,000	100,000	30,000	....
....	12,000	2,145,050	....	1,750,000	....
....	2,637,027	80,000	....	37,000	....
36,000	12,000	101,500	10,000	200,000	1,060,000
....	272,100	703,786	....	15,000	....
102,900	158,000	451,000	1,820,000	....	5,000
....	20,000	1,101,100	....	20,000	....
....	405,000	564,500	....	110,000	....
....	....	....	....	345,000	....
....	....	147,100	....	....	....
....	....	....	....	12,000	....
....	3,500	....	46,600	....	....

TABLE 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD

Industry	Kind of wood			
	Yellow poplar	Cypress	Western yellow pine	Birch
	Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
All industries	680,936,848	668,353,342	563,816,810	481,293,680
Planing-mill products, sash, doors, blinds, and general millwork	236,047,697	508,728,575	264,920,778	133,867,989
Boxes and crates	165,416,737	38,962,895	288,291,927	90,787,900
Car construction	32,439,064	1,676,400	4,242,500	5,830,429
Furniture	53,374,580	3,477,800	1,806,985	54,677,450
Vehicles and vehicle parts	48,665,960	1,320,951	182,300	14,227,125
Woodenware, novelties, and dairymen's poulterers', and apiarists' supplies	7,278,889	8,693,450	262,500	29,547,890
Agricultural implements	12,412,300	2,682,000	219,000	4,704,000
Chairs and chair stock	1,140,000	...	30,000	30,114,332
Handles	211,900	122,000	...	9,908,250
Musical instruments	40,371,925	70,000	...	12,349,055
Tanks and silos	240,000	35,408,575	127,000	...
Ship and boat building	448,077	5,014,741	518,500	1,055,167
Fixtures	14,574,881	3,364,550	961,720	15,255,129
Caskets and coffins	9,640,860	19,157,633	543,500	191,000
Refrigerators and kitchen cabinets	5,985,729	1,700,500	50,000	3,628,106
Matches and toothpicks	500,000	...	...	3,575,000
Laundry appliances	1,026,200	15,321,300	5,000	3,876,500
Shade and map rollers	326,000	20,000	...	93,000
Paving material and conduits	...	...	...	...
Trunks and valises	2,988,500	1,275,000	361,000	71,500
Machine construction	2,208,577	15,868,405	2,000	470,406
Boot and shoe findings	190,000	...	...	7,483,000
Picture frames and molding	2,158,814	451,000	...	3,133,700
Shuttles, spools, and bobbins	701,000	...	...	33,192,000
Tobacco boxes	7,358,919	1,559,027	...	...
Sewing machines	8,039,244	...	...	206,000
Pumps and wood pipe	1,974,000	2,055,000	...	55,500
Pulleys and conveyors	400,000	3,000	5,000	745,000
Professional and scientific instruments	1,001,400	23,000	8,000	1,062,050
Toys	882,000	150,000	...	3,123,950
Gates and fencing	5,000	681,040	33,000	300,000
Sporting and athletic goods	970,200	166,000	...	983,233
Patterns and flasks	344,330	74,000	136,500	7,000
Bungs and faucets	8,010,000	...	1,200	305,000
Plumbers' woodwork	819,000	25,000	...	2,404,500
Electrical machinery and apparatus	561,700	201,000	...	804,200
Mine equipment	86,500	...	...	336,075
Brushes	282,265	30,000	7,000	1,913,000
Dowels	...	...	90,000	8,149,000
Elevators	334,600	10,000	10,000	28,000
Saddles and harness	22,200	...	1,400	10,000
Playground equipment	85,000	...	...	147,500
Butchers' blocks and skewers	...	...	...	240,000
Clocks	1,085,000	...	...	52,044
Signs and supplies	100,600	30,000	1,000,000	...
Printing material	150,000	30,000	...	242,200
Weighing apparatus	73,000	500	...	675,000
Whips, canes, and umbrella sticks	...	...	...	580,000
Brooms and carpet sweepers	...	...	...	530,500
Firearms	...	...	...	...
Artificial limbs	...	...	...	353,000
Tobacco pipes	...	...	...	2,000
Airplanes	4,200	...	...	...

BY THE WOOD-WORKING INDUSTRIES OF THE U. S.—(*Continued.*)

Kind of wood—*Continued*

Hickory	Basswood	Cottonwood	Chestnut	Ash	Beech
Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
389,604,531	369,640,782	322,642,796	298,849,801	295,461,482	278,203,632
2,489,288	60,557,122	21,428,700	82,267,497	21,304,374	58,394,284
767,920	86,979,611	210,519,509	36,216,700	10,507,308	77,899,280
1,226,706	5,148,521	3,037,468	825,074	18,163,433	1,873,700
843,600	33,146,276	5,158,309	44,734,180	15,668,588	21,163,204
239,491,910	6,418,308	33,278,658	972,809	43,974,668	5,497,743
1,567,011	58,563,923	13,315,296	20,853,100	62,635,800	14,101,553
9,860,470	7,861,750	15,143,000	884,000	10,677,400	4,968,490
1,192,200	1,758,338	126,000	5,240,630	2,765,050	27,187,621
120,294,466	2,285,885	27,000	10,000	64,156,872	16,691,207
225	10,968,180	2,351,000	38,125,141	2,377,332	4,186,000
....	5,000	....	15,000	866,000	150,000
110,195	959,000	14,026	751,295	7,985,554	219,366
26,000	7,114,755	1,553,351	8,039,595	2,783,822	1,109,000
....	2,728,038	555,000	46,586,629	20,000	....
150,000	5,221,634	4,420,322	1,508,753	19,066,380	787,000
....	5,575,000	375,000	....	....	....
....	4,980,670	7,991,500	20,500	111,500	9,580,000
2,500	702,500	....	460,000	161,150	362,000
....	....	....	....	....	....
173,700	21,164,406	1,973,325	562,500	534,435	520,000
1,113,135	1,155,403	293,000	272,375	1,404,362	711,000
25,000	3,599,200	5,000	....	....	445,000
10,000	20,340,700	1,000	1,314,650	281,845	1,200,595
872,000	1,947,000	175,000	....	437,000	3,523,500
....	4,206,250	6,750	....	....	....
....	310,000	326,912	540,000	....	....
925,000	....	....	....	975,500	52,500
....	625,000	42,000	120,000	512,100	1,976,000
971,332	2,619,070	170	367,000	123,600	1,259,600
....	8,739,242	257,000	966,268	895,300	3,221,506
600	50,000	....	5,121,500	700	....
4,944,000	318,600	60,000	222,000	3,180,000	212,000
....	123,500	....	175,200	35,000	10,500
6,000	....	....	....	....	850,000
....	245,000	....	114,000	536,000	....
....	299,000	7,500	112,700	87,000	425,000
816,363	....	....	854,405	43,425	1,195,525
125,000	758,300	50,000	31,500	36,400	6,378,894
30,500	167,500	5,000	....	29,000	1,834,000
100	10,000	....	19,000	145,700	....
12,800	52,000	46,000	....	2,103,000	2,658,600
100,000	....	....	....	180,000	3,083,500
1,310,000	....	....	....	20,000	920,000
....	1,415,000	....	290,000	....	9,714
....	100,000	100,000	....	....	....
20,500	352,600	....	255,800	391,000	289,900
....	35,000	....	....	5,900	335,000
84,000	32,500	....	....	30,000	2,822,500
....	....	....	....	236,984	98,350
....	....	....	....	....	....
40,010	1,000	....	....	....	....
....	....	....	....	....	....
2,000	....	....	....	12,000	....

TABLE 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD

Industry	Kind of wood			
	Elm	Tupelo	Redwood	Larch
	Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
All industries	218,200,988	127,958,309	122,326,779	114,029,275
Planing-mill products, sash, doors, blinds, and general millwork	6,218,860	17,003,448	92,759,519	88,484,081
Boxes and crates	63,726,458	74,982,910	2,439,500	7,470,300
Car construction	1,221,121	114,168	120,000	1,537,669
Furniture	12,154,102	2,529,000	355,250	154,000
Vehicles and vehicle parts	31,296,922	1,067,600	259,000	....
Woodenware, novelties, and dairymen's, poulterers', and apiarists' supplies	16,383,426	5,366,900	3,208,150	416,700
Agricultural implements	7,249,000	1,140,000	200,500	100,000
Chairs and chair stock	23,157,586	191,000	....	....
Handles	3,060,307	....	....	....
Musical instruments	15,602,440	460,000	286,200	....
Tanks and silos	15,000	20,000	8,124,938	9,745,000
Ship and boat building	706,600	138,490	837,500	328,525
Fixtures	6,368,275	248,000	1,074,710	2,000
Caskets and coffins	....	500,000	1,782,000	....
Refrigerators and kitchen cabinets	13,046,100	39,500	161,000	56,000
Matches and toothpicks	....	....	....	....
Laundry appliances	1,365,000	3,842,000	13,000	....
Shade and map rollers	....	1,006,000	2,000	....
Paving material and conduits	....	1,050,000	....	4,475,000
Trunks and valises	6,409,286	....	....	....
Machine construction	831,000	27,500	58,500	....
Boot and shoe findings	2,000	....	....	....
Picture frames and molding	43,000	240,000	47,632	....
Shuttles, spools, and bobbins	....	250,000	....	....
Tobacco boxes	1,809,000	10,376,217	61,000	....
Sewing machines	....	2,200,000	16,000	....
Pumps and wood pipe	20,000	529,500	9,117,500	512,000
Pulleys and conveyors	200,000	639,000	....	....
Professional and scientific instruments	200	12,000	31,220	....
Toys	2,042,055	5,000	....	....
Gates and fencing	155,000	....	133,000	48,000
Sporting and athletic goods	3,226,750	20,000	....	....
Patterns and flasks	40,000	500	1,033,200	....
Bungs and faucets	....	....	2,000	....
Plumbers' woodwork	55,000	....	....	....
Electrical machinery and apparatus	463,000	....	....	700,000
Mine equipment	8,800	3,589,760	....	....
Brushes	187,000	1,000	....	....
Dowels	175,000	....	....	....
Elevators	68,500	15,000	36,000	....
Saddles and harness	276,000	20,000	....	....
Playground equipment	334,000	1,000	....	....
Butchers' blocks and skewers	....	....	....	....
Clocks	....	322,816	....	....
Signs and supplies	209,000	....	147,460	....
Printing material	84,200	10,000	20,000	....
Weighing apparatus	....	....	....	....
Whips, canes, and umbrella sticks	....	....	....	....
Brooms and carpet sweepers	....	....	....	....
Firearms	....	....	....	....
Artificial limbs	....	....	....	....
Tobacco pipes	....	....	....	....
Airplanes	....	....	....	....

BY THE WOOD-WORKING INDUSTRIES OF THE U. S.—(*Continued.*)

Kind of wood—*Continued*					
Cedar	Sugar pine	Balsam fir	Mahogany	Spanish cedar	Sycamore
Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
102,248,253	59,211,298	53,262,030	50,575,999	30,323,441	26,052,812
45,187,611	31,795,077	10,863,300	7,336,932	8,123	1,723,550
2,512,150	24,686,000	40,173,700	13,000	...	16,451,693
339,487	61,328	700,750	5,986,198	...	...
1,856,100	375,510	...	15,637,125	2,500	1,474,882
2,500	6,000	1,000	516,399	500	62,600
6,405,470	419,063	586,880	72,305	10,000	607,500
...	50,000	...	500	...	290,000
34,500	...	...	2,455,700	...	971,344
...	...	...	29,000	...	156,000
17,500	1,004,400	101,400	8,610,355	7,750	304,600
4,549,400	10,750	...	...	...	...
6,999,722	200,500	...	1,190,192	27,300	38,000
977,345	206,650	...	5,527,819	...	713,000
5,901,718	...	...	1,528,294	300	...
...	...	710,000	6,800	...	340,000
407,500	...	...	...	...	...
4,867,000	2,000	100,000	...	...	2,000
5,000	30,000	...	5,000	...	202,000
100,000	...	...	...	...	...
6,000	11,000	25,000	500	...	5,000
100	4,000	...	5,885	...	...
...	...	...	...	...	...
...	2,730	...	171,200	...	30,000
...	...	...	...	...	...
246,750	...	...	161,200	30,203,068	430,000
...	...	...	91,878	...	150,000
...	...	...	...	...	...
...	...	...	...	...	...
20,050,000	23,500	...	84,862	...	...
...	...	...	...	...	91,343
465,500	...	...	...	...	...
222,500	...	...	100,000	31,500	30,500
265,400	294,350	...	271,659	31,400	...
30,000	...	...	...	...	...
...	...	...	127,000	...	...
735,000	...	...	301,700	...	...
...	...	...	...	...	...
24,000	3,440	...	35,300	1,000	74,300
18,000	...	...	...	...	...
...	15,000	...	1,000	...	...
...	10,000	...	...	...	34,500
...	...	...	...	...	...
...	...	...	...	...	1,600,000
...	...	...	204,196	...	...
20,000	...	...	...	...	...
...	...	...	48,500	...	...
...	...	...	4,000	...	...
2,000	...	...	15,000	...	...
...	...	...	30,500	...	270,000
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	6,000	...	...

TABLE 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD

Industry	Kind of wood			
	Black walnut	Cherry	White fir	Willow
	Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
All industries	23,988,346	12,047,210	11,338,580	10,664,770
Planing-mill products, sash, doors, blinds, and general millwork	4,606,420	1,674,235	8,162,250	266,000
Boxes and crates	163,250	170,500	3,142,080	10,004,600
Car construction	256,181	1,965,570	...	...
Furniture	1,689,957	622,530	...	40,000
Vehicles and vehicle parts	390,450	39,650	3,000	...
Woodenware, novelties, and dairymen's, poulterers', and apiarists' supplies	38,547	62,350	31,250	128,000
Agricultural implements	8,000	300	...	...
Chairs and chair stock	263,200	56,000	...	...
Handles	29,050	617,500	...	19,000
Musical instruments	4,991,808	334,180	...	...
Tanks and silos	...	500	...	...
Ship and boat building	3,750	184,976	...	1,000
Fixtures	660,635	2,231,750	...	150,000
Caskets and coffins	474,000	33,000	...	...
Refrigerators and kitchen cabinets	...	7,500	...	...
Matches and toothpicks	...	...	...	...
Laundry appliances	20,000	2,000	...	...
Shade and map rollers	2,000	2,000	...	...
Paving material and conduits	...	...	...	...
Trunks and valises	...	...	...	...
Machine construction	10,817	60,500	...	...
Boot and shoe findings	...	25,000	...	...
Picture frames and molding	125,004	10,000	...	...
Shuttles, spools, and bobbins	...	5,000	...	...
Tobacco boxes	...	...	...	...
Sewing machines	7,796,815	...	...	...
Pumps and wood pipe	...	...	...	...
Pulleys and conveyors	...	...	...	...
Professional and scientific instruments	71,200	732,750	...	...
Toys	...	2,000	...	...
Gates and fencing	...	...	...	...
Sporting and athletic goods	41,000	600	...	...
Patterns and flasks	21,500	165,594	...	...
Bungs and faucets	56,000	...	...	...
Plumbers' woodwork	10,300	92,400	...	...
Electrical machinery and apparatus	452,600	27,800	...	...
Mine equipment	...	...	...	...
Brushes	26,700	488,900	...	...
Dowels	...	10,000	...	...
Elevators	...	...	...	...
Saddles and harness	...	...	...	...
Playground equipment	...	15,000	...	...
Butchers' blocks and skewers	...	...	...	...
Clocks	58,527	300,000	...	...
Signs and supplies	...	...	...	...
Printing material	...	2,089,625	...	...
Weighing apparatus	...	7,500	...	...
Whips, canes, and umbrella sticks	20,000	...	...	...
Brooms and carpet sweepers	500	...	...	...
Firearms	1,700,135	...	...	...
Artificial limbs	...	10,000	...	56,170
Tobacco pipes	...	...	...	...
Airplanes	...	...	...	...

BY THE WOOD-WORKING INDUSTRIES OF THE U. S.—(*Continued*:)

Kind of wood—*Continued*

Dogwood	Noble fir	Magnolia	Buckeye	Persimmon	Cucumber	Butternut
Feet b. m. 7,518,177	*Feet b. m.* 6,653,500	*Feet b. m.* 6,156,500	*Feet b. m.* 5,486,047	*Feet b. m.* 3,571,760	*Feet b. m.* 2,660,700	*Feet b. m.* 2,310,793
6,000		116,900	694,400		1,415,800	231,700
	6,653,500	5,449,000	3,174,028		524,000	578,000
						1,300
		477,100	415,000	35,000	16,000	593,500
		9,500	63,419		3,800	11,500
34			83,700		650,000	159,000
					1,100	10,000
						20,546
190,230				7,000		2,000
			6,000			98,100
						78,237
		27,000	10,000			393,600
			207,500		20,000	16,000
			125,000			
						5,000
			415,000			
						5,000
				413,000		
			214,000		20,000	
7,060,425				2,909,760		
		75,000				
					10,000	10,000
31,200						30,000
						10,000
6,000				206,000		
			3,000			42,710
						14,600
147,288						
9,000		2,000		1,000		
1,000						
67,000						
			75,000			

TABLE 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD

Industry	Kind of wood			
	Red alder	Lodgepole pine	Red fir	Circassian walnut
	Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
All industries	2,248,700	1,979,500	1,854,830	1,744,779
Planing-mill products, sash, doors, blinds, and general millwork	436,000	969,500	524,000	740,212
Boxes and crates	....	....	1,328,330	....
Car construction	....	1,000,000	....	1,300
Furniture	792,500	1,000	2,500	452,040
Vehicles and vehicle parts	....	8,000	....	16,820
Woodenware, novelties, and dairymen's, poulterers', and apiarists' supplies	20,000	....	....	14,857
Agricultural implements	....	....	....	....
Chairs and chair stock	625,000	....	....	8,300
Handles	361,700	....	....	....
Musical instruments	....	....	....	268,415
Tanks and silos	....	....	....	....
Ship and boat building	....	....	....	25,000
Fixtures	....	....	....	99,050
Caskets and coffins	....	1,000	....	5,000
Refrigerators and kitchen cabinets	....	....	....	500
Matches and toothpicks	....	....	....	....
Laundry appliances	....	....	....	....
Shade and map rollers	....	....	....	100
Paving material and conduits	....	....	....	....
Trunks and valises	....	....	....	....
Machine construction	....	....	....	....
Boot and shoe findings	....	....	....	....
Picture frames and molding	....	....	....	7,000
Shuttles, spools, and bobbins	....	....	....	....
Tobacco boxes	....	....	....	250
Sewing machines	....	....	....	....
Pumps and wood pipe	....	....	....	....
Pulleys and conveyors	5,500	....	....	....
Professional and scientific instruments	....	....	....	....
Toys	....	....	....	....
Gates and fencing	....	....	....	....
Sporting and athletic goods	....	....	....	25,000
Patterns and flasks	....	....	....	....
Bungs and faucets	....	....	....	....
Plumbers' woodwork	....	....	....	....
Electrical machinery and apparatus	....	....	....	13,400
Mine equipment	....	....	....	....
Brushes	....	....	....	....
Dowels	....	....	....	....
Elevators	....	....	....	....
Saddles and harness	8 000	....	....	....
Playground equipment	....	....	....	....
Butchers' blocks and skewers	....	....	....	....
Clocks	....	....	....	....
Signs and supplies	....	....	....	....
Printing material	....	....	....	....
Weighing apparatus	....	....	....	....
Whips, canes, and umbrella sticks	....	....	....	....
Brooms and carpet sweepers	....	....	....	20,500
Firearms	....	....	....	47,035
Artificial limbs	....	....	....	....
Tobacco pipes	....	....	....	....
Airplanes	....	....	....	....

BY THE WOOD-WORKING INDUSTRIES OF THE U. S.—(*Continued.*)

Kind of wood—*Continued*

Padouk	Hackberry	Lignum-vitæ	Teak	West Indian boxwood	Alpine fir	Locust
Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
1,386,530	1,128,000	952,126	926,969	870,412	780,000	639,228
333,792	441,000	....	114,245	....	270,000	220,000
....	315,000	....	....	....	500,000	....
723,063	....	....	31,000	....	....	....
230,100	70,000	593,663	1,690	....	....	2,000
1,000	100,000	....	....	....	....	110,350
....	150,000	1,000	....	2,100	10,000	50,500
....	....	....	....	....	....	....
3,000	....	....	....	....	....	....
....	....	1,500	....	37,556	....	4,000
....	....	....	....	70,328	....	....
....	....	....	....	....	....	....
8,375	....	10,631	764,309	....	....	215,028
85,000	6,000	785	1,125	....	....	1,000
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	2,000	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	961	....		....	2,500
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	103,440	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	72,300	....	....	....	....
....	....	37,236	1,000	653,848	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	234,050	10,000	....	....	....
1,600	....	....	1,600	....	....	500
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	2,000
....	....	....	....	....	....	31,350
600	....	....	....	3,140	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	46,000	....	....	....	....	....
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TABLE. 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD

Industry	Kind of wood			
	Horn-beam	Ebony	Osage orange	Rose-wood
	Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
All industries	608,484	528,812	520,076	471,734
Planing-mill products, sash, doors, blinds, and general millwork	19,000	50,600		6,100
Boxes and crates				
Car construction			30,000	37,000
Furniture	15,000	5,450	1,000	15,280
Vehicles and vehicle parts	126,000		439,026	1,100
Woodenware, novelties, and dairymen's, poulterers', and apiarists' supplies	10,000	1,045	50,000	3,613
Agricultural implements	1,200			
Chairs and chair stock				
Handles	415,500	4,664		15,456
Musical instruments		60,373		49,645
Tanks and silos				
Ship and boat building			50	1,600
Fixtures		1,800		52,925
Caskets and coffins				
Refrigerators and kitchen cabinets				
Matches and toothpicks				
Laundry appliances				
Shade and map rollers				1,000
Paving material and conduits				
Trunks and valises				
Machine construction	100			
Boot and shoe findings				
Picture frames and molding		1,330		2,420
Shuttles, spools, and bobbins				
Tobacco boxes				100
Sewing machines				
Pumps and wood pipe				
Pulleys and conveyors				
Professional and scientific instruments		500		219,353
Toys				
Gates and fencing				
Sporting and athletic goods		189,000		24,400
Patterns and flasks				
Bungs and faucets				10,642
Plumbers' woodwork				1,000
Electrical machinery and apparatus				2,260
Mine equipment	21,684			
Brushes		10,100		12,050
Dowels				
Elevators				
Saddles and harness				
Playground equipment				
Butchers' blocks and skewers				
Clocks				290
Signs and supplies				
Printing material				
Weighing apparatus				
Whips, canes, and umbrella sticks		194,150		
Brooms and carpet sweepers				5,500
Firearms				
Artificial limbs				10,000
Tobacco pipes		9,800		
Airplanes				

BY THE WOOD-WORKING INDUSTRIES OF THE U. S.—(*Continued.*)

Kind of wood—*Continued*

Prima vera	Sassafras	Eucalyptus	Apple-wood	Cocobola	Yucca	Holly	Laurel
Feet b. m. 380,568	*Feet b. m.* 360,268	*Feet b. m.* 338,800	*Feet b. m.* 320,935	*Feet b. m.* 279,400	*Feet b. m.* 172,300	*Feet b. m.* 86,680	*Feet b. m.* 72,400
121,973	336,000	4,200	....	....	60,000	500	1,600
....	....	....	13,800	....	3,500	....	....
25,350	....	....	....	....	....	....	....
67,500	12,000	5,500	500	....	....	100	13,600
....	....	40,950	1,000	....		....	....
....	1,500	....	....	2,400	69,000	60,000	4,200
....	....	10,000	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	156,400	210,000	....	....	....
4,300	....	1,000	....	....	....	3,580	....
....	....	....	....	....		....	....
31,750	50	273,050	1,500	200	....	....	47,500
129,595	10,000	100	....	....	....	....	500
....	718	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
100	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	4,000	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	300	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	25,000	64,800	....	....	....
....	....	....	....	....			....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	1,500	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	2,000	....	21,000	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	1,000	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	5,000
....	....	....	....	....	....	....	....
....	....	....		....	39,800	....	....
....	....	....	121,435	....	....	....	....
....	....	....	....	....	....	....	....

TABLE 26.—AVERAGE ANNUAL CONSUMPTION OF WOOD BY THE WOODWORKING INDUSTRIES OF THE U. S.—(*Concluded.*)

Industry	Kind of wood				
	Satinwood	Koko	Turkish boxwood	Miscellaneous foreign	Miscellaneous native
	Feet b. m.	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
All industries	67,958	32,600	29,189	630,345	432,158
Planing-mill products, sash, doors, blinds, and general millwork	34,000			106,125	261,750
Boxes and crates					101,308
Car construction	288	32,000		46,000	
Furniture	22,070			46,580	15,650
Vehicles and vehicle parts				330	8,000
Woodenware, novelties, and dairymen's, poulterers', and apiarists' supplies					12,450
Agricultural implements					10,000
Chairs and chair stock					
Handles			225	985	
Musical instruments	5,100		25	625	
Tanks and silos					
Ship and boat building				20,500	1,000
Fixtures	1,000	500		17,000	
Caskets and coffins	5,000				
Refrigerators and kitchen cabinets					
Matches and toothpicks					
Laundry appliances					
Shade and map rollers		100			
Paving material and conduits					
Trunks and valises					
Machine construction					
Boot and shoe findings					
Picture frames and molding				2,250	
Shuttles, spools, and bobbins			1,575	40	
Tobacco boxes				36,600	
Sewing machines					
Pumps and wood pipe					
Pulleys and conveyors					
Professional and scientific instruments					
Toys					
Gates and fencing					
Sporting and athletic goods					
Patterns and flasks					
Bungs and faucets					
Plumbers' woodwork					
Electrical machinery and apparatus					
Mine equipment					
Brushes	500			1,000	
Dowels					
Elevators					
Saddles and harness					
Playground equipment					
Butchers' blocks and skewers					
Clocks					
Signs and supplies					
Printing material			33		
Weighing apparatus					
Whips, canes, and umbrella sticks			25,600	30	
Brooms and carpet sweepers					
Firearms			1,731		
Artificial limbs				30,000	
Tobacco pipes				322,280	22,000
Airplanes					

All imported woods used by factories are included in Table 26.

Wood used for lath, shingles, cooperage, veneer, pulp, distillation, poles, and ties is not covered in Table 26.

The scope of the statistics for the industries with titles that are not entirely descriptive is as follows: Planing-mill products cover standard patterns, such as flooring, ceiling, and siding, made in large quantities by planing mills in lumber-producing regions; while sash, doors, blinds, and millwork usually are made in millwork plants in the consuming regions. However, considerable quantities of doors and door stock are made in the producing regions of the Pacific Coast States. Boxes and crates cover all kinds of packing boxes and crates made of lumber or veneer, also fruit and vegetable packages and baskets. Car construction covers wooden construction in all types of railroad and electric cars, as well as in locomotives and mine cars. Furniture includes household and office furniture, except chairs, kitchen furniture, and fixtures in business buildings. Vehicles take in horse vehicles, automobiles, bicycles, pushcarts, and wheelbarrows. Woodenware and novelties embrace a thousand or more articles, such as kitchen utensils, wooden dishes, butter and cheese packages, measures, pails, wooden novelties of all kinds, ladders, and supplies for dairymen, poulterers, and apiarists. Fixtures are such as show cases, counters, bars, and lodge and church furnishings. Shade and map rollers include also curtain and rug poles and venetian blinds. Machine construction means wooden construction in machinery of all kinds. Shoe lasts, pegs, and shanks are boot and shoe findings. Four-sevenths of the wood used for professional and scientific instruments went into pencils, the rest into artists', photographers', and draftsmen's instruments, rules, and scientific apparatus. Billiard and pool tables, as well as gymnasium goods and all outdoor sporting goods, come under sporting and athletic goods. Mine equipment includes ventilating apparatus, brattices, breaker equipment, slope rollers, and sprags. Dowels are small rods used in fastening together furniture, fixtures, and doors. Under playground equipment are included lawn swings and porch furniture.

The kinds of wood are classified according to rather broad commercial practice. The classification is practically the same as that used in the lumber census bulletins; figures on the several species of each family or group are combined under the common name.

Oak, maple, spruce, hemlock, birch, hickory, basswood, ash, elm, cedar,[1] willow, locust, and eucalyptus cover each its different species. Yellow pine includes the southern yellow pines, North Carolina pines, and minor eastern yellow pines. Western yellow pine is listed separately; trade names for it are western pine, western soft pine, and California white pine.

White pine covers both northern and western (Idaho) white pine as well as Norway pine and jack pine.

Cottonwood takes in the cottonwoods, aspen (or popple), and balm of Gilead.

Tupelo includes cotton gum (called tupelo commercially), black gum, and water gum.

Larch includes western larch and eastern tamarack.

Mahogany covers all woods sold in this country as such.

White fir includes the botanical white fir as well as grand and silver (amabilis) fir. The other minor firs, noble, red and alpine fir, usually sold as white fir, are listed separately.

All other kinds of wood listed are single species, except that cypress, sycamore, cherry, dogwood, magnolia (cucumber, of the magnolia family, is shown separately), and buckeye are family names, but only one species of each is used commercially. Redwood sometimes includes lumber from the bigtree. The red-gum tree yields both commercial red and sap gum and both are covered in Table 26 by red gum.

Figure 108 shows graphically the comparative amounts of wood used by the larger industries in each State.

Amount of Wood Used Annually for all Purposes.—The average amount of wood used annually in the United States for the last few years for lumber and manufactured products has been about 52 billion board feet. This is made up of sawed lumber, ties, mine timbers, wood used for paper pulp, distillation, etc., but does not include fuel, fence posts, and rails. The total amount of wood used annually is estimated at about 100 billion board feet. Table 27 gives the quantities of wood used annually in the United States for various purposes.

[1] Spanish cedar is listed separately.

TABLE 27.—AMOUNT OF WOOD USED ANNUALLY IN THE UNITED STATES FOR VARIOUS PURPOSES[1]

Industry	Quantity used annually
	Feet b. m.
Construction timber and lumber	14,484,568,000
Planing-mill products, sash, doors, and general millwork	13,428,862,000
Boxes and crates	4,547,973,000
Ties	4,501,767,000
Mine timbers	2,422,375,000
Pulp	2,154,025,000
Car construction	1,262,090,000
Shingles	1,203,769,000
Furniture	944,678,000
Vehicles	739,124,000
Slack cooperage	655,603,000
Distillation	610,680,000
Lath	543,833,000
Tight cooperage	478,438,000
Veneers	444,886,000
Woodenware and novelties	405,286,000
Agricultural implements	321,239,000
Chairs	289,791,000
Handles	280,235,000
Musical instruments	260,195,000
Tanks and silos	225,618,000
Poles	204,000,000
Ship and boat building	199,598,000
Fixtures	187,133,000
Caskets and coffins	153,395,000
Refrigerators and kitchen cabinets	137,616,000
Excelsior	100,247,000
Miscellaneous secondary industries (39) and extract wood	1,195,110,000
Total (lumber and manufactured products)	52,382,134,000
Firewood	42,968,000,000
Posts and rails	6,000,000,000
Grand total	101,350,134,000

[1] Based on 1912 lumber cut.

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